REPORT

OF THE

SEVENTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT LIVERPOOL IN SEPTEMBER 1837.

VOL. VI.

LONDON:

JOHN MURRAY, ALBEMARLE STREET.

1838.

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OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

The Association contemplates no interference with the ground occupied by other Institutions. Its objects are,—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another, and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind, which impede its progress.

RULES.

MEMBERS.

All Persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or managing Committees, of Philosophical Institutions, shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee, shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Members of the Association, subject to the approval of a General Meeting.

SUBSCRIPTIONS.

The amount of the Annual Subscription shall be One Pound, to be paid in advance upon admission; and the amount of the composition in lieu thereof, Five Pounds.

Subscriptions shall be received by the Treasurer or Secretaries.

If the annual subscription of any Member shall have been in arrear for two years, and shall not be paid on proper notice, he shall cease to be a member; but it shall be in the power of the Committee or Council to reinstate him, on payment of arrears.

MEETINGS.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee at the previous Meeting; and the Arrangements for it shall be entrusted to the Officers of the Association.

GENERAL COMMITTEE*.

The General Committee shall sit during the time of the Meeting, or longer, to transact the business of the Association. It shall consist of all Members present, who have communicated any scientific Paper to a Philosophical Society, which Paper has been printed in its Transactions, or with its concurrence.

Members of Philosophical Institutions, being Members of this Association, who may be sent as Deputies to any Meeting of the Association, shall be Members of the Committee for that Meeting, the number being limited to two from each Institution.

SECTIONAL COMMITTEES.

The General Committee shall appoint, at each Meeting, Committees, consisting severally of the Members most conversant with the several branches of Science, to advise together for the advancement thereof.

The Committees shall report what subjects of investigation they would particularly recommend to be prosecuted during the ensuing year, and brought under consideration at the next Meeting.

* The constitution of the General Committee was discussed at Liverpool, and at the close of the meeting notice was given, that attention would be directed to the reconsideration of the laws of the constitution of the General Committee at the next meeting of the Association in Newcastle.

The Committees shall recommend Reports on the state and progress of particular Sciences, to be drawn up from time to time by competent persons, for the information of the Annual Meetings.

COMMITTEE OF RECOMMENDATIONS.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of science.

LOCAL COMMITTEES.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

OFFICERS.

A President, two or more Vice-Presidents, two or more Secretaries, and a Treasurer, shall be annually appointed by the General Committee.

COUNCIL.

In the intervals of the Meetings the affairs of the Association shall be managed by a Council, appointed by the General Committee. The Council may also assemble for the dispatch of business during the week of the Meeting.

PAPERS AND COMMUNICATIONS.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

ACCOUNTS.

The Accounts of the Association shall be audited annually, by Auditors appointed by the Meeting.

OFFICERS AND COUNCIL, 1837–38.

Trustees (permanent.)—Charles Babbage, Esq. R. I. Murchison, Esq. John Taylor, Esq.

President.—The Earl of Burlington.

President elect.—His Grace the Duke of Northumberland.

Vice-Presidents.—The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.

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General Secretaries.—R. I. Murchison, Esq. Rev. Professor Peacock.

Assistant General Secretary.—Professor Phillips, York.

Secretaries for Newcastle.—J. Adamson, Esq. William Hutton, Esq. Professor Johnston.

Treasurer.—John Taylor, Esq., 2, Duke Street, Adelphi.

Treasurers to the Newcastle Meeting.—Rev. W. Turner. Charles Bigge, Esq.

Council—Francis Baily, Esq., Treas. R.S. Professor Christie, Woolwich. Professor Graham, London. J. E. Gray, British Museum. G. B. Greenough, Esq., Regent's Park. Professor Henslow, Cambridge. Dr. Hodgkin. Rev. F. W. Hope. Robert Hutton, Esq., M.P. W. S. MacLeay, Esq. Professor Powell, Oxford. Dr. Roget. Colonel Sykes.

Secretary to the Council.—James Yates, Esq., 49, Upper Bedford Place, London.

Local Treasurers.—Dr. Daubeny, Oxford. Professor Henslow, Cambridge. Dr. Orpen, Dublin. Charles Forbes, Esq., Edinburgh. William Gray, jun., Esq., York. George Bengough, Esq., Bristol. Samuel Turner, Esq., Liverpool. Rev. John James Tayler, Manchester. James Russell, Esq., Birmingham. William Hutton, Esq., Newcastle-upon-Tyne. Henry Woollcombe, Esq., Plymouth.

OFFICERS OF SECTIONAL COMMITTEES AT THE LIVERPOOL MEETING.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President.—Sir D. Brewster.

Vice-Presidents.—J. W. Lubbock, Esq. F. Baily, Esq. Rev. Professor Peacock.

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President.—Dr. Faraday.

Vice-Presidents.—Professor Daniell. Professor Graham. Dr. Apjohn.

Secretaries.—Professor Johnston. Dr. Reynolds. Professor Miller.

SECTION C.—GEOLOGY AND GEOGRAPHY.

President.—Rev. Professor Sedgwick. (For Geography) G. B. Greenough, Esq.

Vice-Presidents.—Leonard Horner, Esq. Lord Cole. H. T. De la Beche, Esq.

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President.—W. S. MacLeay, Esq.

Vice-Presidents.—Dr. Richardson. Professor Graham. Professor Lindley.

Secretaries.—C. C. Babington, Esq. W. Swainson, Esq. Rev. L. Jenyns.

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President.—Professor W. Clark, M.D.

Vice-Presidents.—James Carson, M.D. Peter Mark Roget, M.D. Robert Bickersteth, Esq. Professor R. T. Evanson, M.D.

Secretaries.—James Carson, Jun., M.D. J. R. W. Vose, M.D. James Long, Esq.

SECTION F.—STATISTICS.

President.—Lord Sandon.
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Secretaries.—W. R. Greg, Esq. Dr. W. C. Taylor. W. Langton, Esq.

SECTION G.—MECHANICAL SCIENCE.

President.—Rev. T. R. Robinson, D.D.
Vice-Presidents.—Dr. Lardner. Professor Wheatstone. Professor Willis.
Secretaries.—Thomas Webster, Esq. Charles Vignolles, Esq.

CORRESPONDING MEMBERS.

Professor Agassiz, Neufchatel. M. Arago, Secretary of the Institute, Paris. Professor Berzelius, Stockholm. Professor De la Rive, Geneva. Professor Dumas, Paris. Baron Alexander von Humboldt, Berlin. Professor Liebig, Giessen. Professor Œrsted, Copenhagen. Jean Plana, Astronomer Royal, Turin. M. Quetelet, Brussels. Professor Schumacher, Altona.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

TREASURER'S ACCOUNT from 15th July 1836 to 31st July 1837.

RECEIPTS.

	£	s.	d.
Balance in hand from last year's Account	607	13	3
Compositions from 209 Members	985	0	0
Subscriptions 1836, 1121 do.	1121	0	0
Ditto 1837, 25 do.	25	0	0
Arrears 1835, 24 do.	24	0	0
Dividend on £4500 in 3 per cent. consols, 12 months to 5th July last	135	0	0
Received on account of Sale of Reports, 1st vol., 2nd edit.	43	7	0
Ditto ditto 2nd vol.	56	13	6
Ditto ditto 3rd vol.	104	10	0
Ditto ditto 4th vol.	203	7	2
Ditto ditto Lithographs	7	17	3
	£3313	8	2

R. HUTTON,
G. R. PORTER,
J. W. LUBBOCK, } *Auditors.*

PAYMENTS.

	£	s.	d.	£	s.	d.
Expenses of Meeting at Bristol				265	10	6
Disbursements by Local Treasurers				135	14	0
Purchase of £1000 in 3 per cent. Consols				887	10	0
Salaries to Assistant Secretary and Accountant, 12 months to Christmas last				230	0	0
Grants for Scientific purposes, viz.:						
Committee for Discussion of Tides (1835)	97	10	0			
Ditto ditto (1836)	186	11	0			
Ditto ditto at Bristol	150	0	0			
Ditto on Lunar Nutation	70	0	0			
Ditto on Meteorology and Subterranean Temperature	93	3	0			
Ditto Mechanism of Waves	100	12	0			
Ditto Experiments on the Heart	8	4	6			
Ditto Atmospheric Air, Barometers	11	18	6			
Ditto Barometrical Observations	30	0	0			
Ditto Experiments on Vitrification	150	0	0			
Ditto Chemical Constants, Printing	24	13	6			
				922	12	6
Paid Richard Taylor, printing Reports, 4th vol. (including Notices of Communications and Lists of Members)				455	5	5
Paid J. W. Lowry, Engraving for ditto				84	5	7
Sundry Expenses on Publishing the Reports				52	18	5
Sundry Printing, Advertising, &c.				31	11	3
Balance in the hands of Bankers	170	9	1			
Ditto Treasurer	14	5	10			
Ditto Local Treasurers	63	5	7			
				248	0	6
				£3313	8	2

The following Reports on the progress and desiderata of different branches of science have been drawn up at the request of the Association, and printed in its Transactions.

Vol. I.

On the progress of Astronomy during the present century, by G. B. Airy, M.A., Astronomer Royal.

On the state of our knowledge respecting Tides, by J. W. Lubbock, M.A., Vice-President of the Royal Society.

On the recent progress and present state of Meteorology, by James D. Forbes, F.R.S., Professor of Natural Philosophy, Edinburgh.

On the present state of our knowledge of the Science of Radiant Heat, by the Rev. Baden Powell, M.A., F.R.S., Savilian Professor of Geometry, Oxford.

On Thermo-electricity, by the Rev. James Cumming, M.A., F.R.S., Professor of Chemistry, Cambridge.

On the recent progress of Optics, by Sir David Brewster, K.C.G., LL.D., F.R.S., &c.

On the recent progress and present state of Mineralogy, by the Rev. William Whewell, M.A., F.R.S.

On the progress, actual state, and ulterior prospects of Geology, by the Rev. William Conybeare, M.A., F.R.S., V.P.G.S., &c.

On the recent progress and present state of Chemical Science, by J. F. W. Johnston, A.M., Professor of Chemistry, Durham.

On the application of Philological and Physical researches to the History of the Human Species, by J. C. Prichard, M.D., F.R.S., &c.

Vol. II.

On the advances which have recently been made in certain branches of Analysis, by the Rev. G. Peacock, M.A., F.R.S., &c.

On the present state of the Analytical Theory of Hydrostatics and Hydrodynamics, by the Rev. John Challis, M.A., F.R.S., &c.

On the state of our knowledge of Hydraulics, considered as a branch of Engineering, by George Rennie, F.R.S., &c. (Parts I. and II.)

On the state of our knowledge respecting the Magnetism of the Earth, by S. H. Christie, M.A., F.R.S., Professor of Mathematics, Woolwich.

On the state of our knowledge of the Strength of Materials, by Peter Barlow, F.R.S.

On the state of our knowledge respecting Mineral Veins, by John Taylor, F.R.S., Treasurer G.S., &c.

On the state of the Physiology of the Nervous System, by William Charles Henry, M.D.

On the recent progress of Physiological Botany, by John Lindley, F.R.S., Professor of Botany in the University of London.

VOL. III.

On the Geology of North America, by H. D. Rogers, F.G.S.

On the philosophy of Contagion, by Wm. Henry, M.D., F.R.S.

On the state of Physiological Knowledge, by the Rev. William Clark, M.D., F.G.S., Professor of Anatomy, Cambridge.

On the state and progress of Zoology, by the Rev. Leonard Jenyns, M.A., F.L.S., &c.

On the theories of Capillary Attraction, and of the Propagation of Sound as affected by the development of Heat, by the Rev. John Challis, M.A., F.R.S., &c.

On the state of the science of Physical Optics, by the Rev. H. Lloyd, M.A., Professor of Natural Philosophy, Dublin.

VOL. IV.

On the state of our knowledge respecting the application of Mathematical and Dynamical principles to Magnetism, Electricity, Heat, &c., by the Rev. Wm. Whewell, M.A., F.R.S.

On Hansteen's researches in Magnetism, by Captain Sabine, F.R.S.

On the state of Mathematical and Physical Science in Belgium, by M. Quetelet, Director of the Observatory, Brussels.

VOL. V.

On the present state of our knowledge with respect to Mineral and Thermal Waters, by Charles Daubeny, M.D., F.R.S., M.R.I.A., &c., Professor of Chemistry and of Botany, Oxford.

On North American Zoology, by John Richardson, M.D., F.R.S., &c.

Supplementary report on the Mathematical Theory of Fluids, by the Rev. J. Challis, Plumian Professor of Astronomy in the University of Cambridge.

VOL. VI.

On the variations of the Magnetic Intensity observed at different points of the Earth's Surface, by Major Edward Sabine, R.A., F.R.S.

On the various modes of Printing for the use of the Blind, by the Rev. William Taylor, F.R.S.

On the present state of our knowledge in regard to Dimorphous Bodies, by Professor Johnston.

On the Statistics of the Four Collectorates of Dukhun, under the British Government.

The following Reports of Researches undertaken at the request of the Association have been published, viz.

Vol. IV.

On the comparative measurement of the Aberdeen Standard Scale, by Francis Baily, Treasurer R.S., &c.

On Impact upon Beams, by Eaton Hodgkinson.

Observations on the Direction and Intensity of the Terrestrial Magnetic Force in Ireland, by the Rev. H. Lloyd, Capt. Sabine, and Capt. J. C. Ross.

On the Phænomena usually referred to the Radiation of Heat, by H. Hudson, M.D.

Experiments on Rain at different elevations, by Wm. Gray, jun. and Professor Phillips.

Hourly observations of the Thermometer at Plymouth, by W. S. Harris.

On the Infra-orbital Cavities in Deers and Antelopes, by A. Jacob, M.D.

On the Effects of Acrid Poisons, by T. Hodgkin, M.D.

On the Motions and Sounds of the Heart, by the Dublin Sub-Committee.

On the Registration of Deaths, by the Edinburgh Sub-Committee.

Vol. V.

Observations on the Direction and Intensity of the Terrestrial Magnetic Force in Scotland, by Major Edward Sabine, R.A., F.R.S., &c.

Comparative view of the more remarkable Plants which characterize the Neighbourhood of Dublin, the Neighbourhood of Edinburgh, and the South-west of Scotland, &c.; drawn up for the British Association, by J. T. Mackay, M.R.I.A., A.L.S., &c., assisted by Robert Graham, Esq., M.D., Professor of Botany in the University of Edinburgh.

Report of the London Sub-Committee of the Medical Section of the British Association on the Motions and Sounds of the Heart.

Second Report of the Dublin Sub-Committee on the Motions and Sounds of the Heart. (See vol. iv. p. 243.)

Report of the Dublin Committee on the Pathology of the Brain and Nervous System.

Account of the recent Discussions of Observations of the Tides which have been obtained by means of the grant of Money which was placed at the disposal of the Author for that purpose at the last Meeting of the Association, by J. W. Lubbock, Esq.

Observations for determining the refractive Indices for the Standard Rays of the Solar Spectrum in various media, by the Rev. Baden Powell, M.A., F.R.S., Savilian Professor of Geometry in the University of Oxford.

Provisional Report on the Communication between the Arteries and Absorbents on the part of the London Committee, by Dr. Hodgkin.

Report of Experiments on Subterranean Temperature, under the direction of a Committee, consisting of Professor Forbes, Mr. W. S. Harris, Professor Powell, Lieut. Colonel Sykes, and Professor Phillips, (Reporter.)

Inquiry into the Validity of a Method recently proposed by George B. Jerrard, Esq., for Transforming and Resolving Equations of Elevated Degrees: undertaken at the request of the Association by Professor Sir W. R. Hamilton.

Vol. VI.

Account of the discussions of Observations of the Tides which have been obtained by means of the grant of money which was placed at the disposal of the Author for that purpose at the last Meeting of the Association, by J. W. Lubbock, Esq., F.R.S.

On the difference between the Composition of Cast Iron produced by the Cold and the Hot Blast, by Thomas Thomson, M.D., F.R.S., L. & E., &c., Professor of Chemistry, Glasgow.

On the Determination of the Constant of Nutation by the Greenwich Observations, made as commanded by the British Association, by the Rev. T. R. Robinson, D.D.

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Report from the Committee for making experiments on the Growth of Plants under Glass, and without any free communication with the outward air, on the plan of Mr. N. I. Ward, of London.

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son, K.H., Secretary of the Royal Society of Edinburgh, and John Scott Russell, Esq., M.A., F.R.S., Edin. (Reporter).

On the relative strength and other Mechanical Properties of Cast Iron obtained by Hot and Cold Blast, by Eaton Hodgkinson.

On the Strength and other Properties of Iron obtained from the Hot and Cold Blast, by W. Fairbairn.

The following Reports and Continuations of Reports have been undertaken to be drawn up at the request of the Association.

On the progress of Electro-chemistry and Electro-magnetism, so far as regards the experimental part of the subject, by P. M. Roget, M.D., Sec. R.S.

On the Connexion of Electricity and Magnetism, by S. H. Christie, Sec. R.S.

On the state of knowledge of the Phænomena of Sound, by Rev. Robert Willis, M.A., F.R.S., &c.

On the state of our knowledge respecting the relative level of Land and Sea, and the waste and extension of the land on the east coast of England, by R. Stevenson, Engineer to the Northern Lighthouses, Edinburgh.

On the Botany of North America, by Jacob Greene, M.D., and Professor Sir W. J. Hooker, M.D.

On the Geographical Distribution of Insects, and particularly of the order Coleoptera, by J. Wilson, F.R.S.E.

On circumstances in Vegetation influencing the Medicinal Virtues of Plants, by R. Christison, M.D.

On Salts, by Professor Graham, F.R.S.

On the progress of Medical Science in Germany, by Dr. Graves.

On the Differential and Integral Calculus, by Rev. Professor Peacock, M.A., F.R.S., &c.

On the Geology of North America, by H. D. Rogers, F.G.S., Professor of Geology, Philadelphia.

On the Mineral Riches of Great Britain, by John Taylor, F.R.S., G.S.

On Vision, by Professor C. Wheatstone, F.R.S.

On the application of a General Principle in Dynamics to the Theory of the Moon, by Professor Sir W. Hamilton.

On Isomeric Bodies, by Professor Liebig.

On Organic Chemistry, by Professor Liebig.

On Inorganic Chemistry, by Professor Johnston, F.R.S.

On Fossil Reptiles, by Professor Owen, F.R.S.

On the Salmonidæ of Scotland, by Sir J. W. Jardine.

On the Caprimulgidæ, by N. Gould, F.L.S.

On the Genera of Fossil Insects, by Rev. F. W. Hope, F.L.S., &c.

*Reports requested, Researches recommended, and Desiderata noticed by the Committees of Science at the Liverpool Meeting *.*

ASTRONOMY.

For the reduction of observations on Stars in the Histoire Céleste and the volumes of the Académie des Sciences for 1789 and 1790 (see vol. iv. p. xv.) *500l.* was placed at the disposal of a Committee, consisting of Mr. Baily, Prof. Airy, and Rev. Dr. Robinson.

For the extension of the Catalogue of the Astronomical Society, so as to include all the stars in Bessel's Fundamenta Astronomiæ, as well as some other stars both in the northern and southern hemisphere, which have since been found to come within the original scope and intention of that Catalogue, or which from peculiar circumstances of position, magnitude, discordance, or proper motion, might advantageously be included therein (the whole of the stars to be reduced to the year 1850, and the constants of precession, aberration and nutation to be computed for that epoch, with their secular variations), the sum of *500l.* was placed at the disposal of a Committee, consisting of Mr. Baily, Prof. Airy, and Rev. Dr. Robinson.

A Committee was appointed, consisting of Rev. Dr. Robinson, Mr. Baily, and Dr. Traill, to apply to the proper authorities for the establishment of an astronomical observatory at Liverpool.

A Committee was appointed, consisting of the President, the Earl of Burlington, Mr. Lubbock, the Astronomer Royal, Mr. Baily, Prof. Rigaud, Prof. Challis, Prof. Sir W. Hamilton, Prof. Peacock, and Rev. Dr. Robinson, for the purpose of representing to Government the importance of reducing the Greenwich observations of the moon.

TIDES.

For completing the discussions of Tides of the port of Bristol, under the direction of Rev. Wm. Whewell, the sum of *75l.* was granted.

A committee was appointed, consisting of Mr. Whewell, Mr. Lubbock, and Dr. Traill, to apply to the proper authorities for the establishment of tide observations at Liverpool.

* In addition to or extension of those contained in vol. iv. and vol. v.

WAVES.

For continuing the experimental investigations on Waves, 100*l.* was placed at the disposal of Sir J. Robison and Mr. Russell.

METEOROLOGY.

The Committee for Meteorology and Subterranean Temperature received a further grant of 100*l.*

For hourly observations of the Barometer and Wet-bulb Thermometer a grant of 50*l.* was placed at the disposal of Mr. W. S. Harris.

For the construction of an Anemometer, on Mr. Osler's plan, the sum of 40*l.* was placed at the disposal of Mr. W. S. Harris and Mr. Osler.

For the repairs of an Anemometer, on Mr. Whewell's plan, 10*l.* was placed at the disposal of Mr. W. S. Harris.

Application was directed to be made to the Dock Committee of Liverpool, requesting that body to direct Meteorological Observations to be made and recorded at the lighthouses and telegraphs under their direction, in conformity with any instructions they may receive from the Meteorological Committee.

OPTICS.

For the purpose of an inquiry into the action of Gases on the Solar Spectrum 100*l.* was placed at the disposal of Sir D. Brewster.

For the purpose of constructing a Telescopic Lens of Rock Salt, the grant of 80*l.*, at the disposal of Sir D. Brewster, was renewed.

Prof. Wheatstone was requested to present a Report on Vision to the next Meeting of the Association.

Prof. Sir W. Hamilton was requested to consider and report on the question of the practicability of applying his general method of Dynamics to improve the Theory of the Moon.

CHEMISTRY.

For experiments on substances present in minute quantities in Atmospheric Air the sum of 10*l.* was placed at the disposal of Mr. West.

For a continuation of his Table of Chemical Constants the sum of 30*l.* was placed at the disposal of Prof. Johnston.

For the institution of a series of experiments on the great scale on the chemical and mechanical effects and changes produced on Cast and Wrought Iron, by the continued action of Sea Water at various temperatures, and of foul River Water, whether fresh or salt, the sum of *20l.* was placed at the disposal of Prof. Davy and Mr. R. Mallet.

For the prosecution of experiments on the Action of Heat of 212° on Organic and Inorganic Bodies the sum of *10l.* was placed at the disposal of Mr. R. Mallet.

Prof. Liebig was requested to prepare a REPORT on the present state of our knowledge in regard to Isomeric Bodies. He was also requested to prepare a REPORT on the state of Organic Chemistry and Organic Analysis.

Prof. Johnston was requested to prepare a REPORT on the state of Inorganic Chemistry and Inorganic Analysis.

GEOLOGY.

For the purpose of carrying on the inquiry into the permanence of the Relative Level of Land and Sea, the sum of *272l.*, the remainder of the vote of last year (500), was placed at the disposal of a Committee, consisting of Rev. W. Whewell, Col. Colby, Mr. Greenough, and Mr. Griffith.

For the purpose of advancing our knowledge of Fossil Ichthyology, by assisting the publication of M. Agassiz, the further sum of *105l.* was placed at the disposal of a Committee, consisting of Dr. Buckland, Prof. Sedgwick and Mr. Murchison.

For the purpose of making excavations in the Peat Mosses of Ireland the grant of *50l.*, at the disposal of Col. Colby, was renewed.

For the purpose of making experiments on the quantity of Mud in Rivers the grant of *20l.* was renewed, and placed at the disposal of a Committee, consisting of Mr. James Yates, Mr. De la Beche and Capt. Denham.

It was stated to be desirable that a REPORT should be drawn up on the present state of our knowledge of the effects of Volta and Thermo-Electricity in the production of Crystals and the modification of Mineral Substances, and the Council of the Association was requested to take steps for obtaining such a report.

Prof. Owen was requested to draw up a REPORT on the present state of our knowledge of the Fossil Reptiles of Great Britain.

It was stated to be desirable that Engineers and Proprietors of Railways should be requested (where it is necessary to cover up sections) to preserve Notes and Drawings of such sections, and to collect the Organic Fossils, if any, and to transmit the same to the Geological Society of London.

The attention of geological observers was directed to the different *varieties* of superficial Gravel and Detritus; their *origin*, whether fresh-water or marine; their *composition*, whether of erratic or of local materials; their *position* with respect to the present form of the surface and one another; their *organic remains*, and other peculiarities.

NATURAL HISTORY.

The following reports and monographs were requested in addition to such as are mentioned in vol. v. p. xv.

On the species of Salmonidæ found in Scotland by Sir W. Jardine.

On the Caprimulgidæ, by Mr. Gould.

On the Genera of Fossil Insects belonging to Great Britain and Ireland, by the Rev. W. F. Hope.

For the purpose of collecting materials towards a Fauna of Ireland, a Committee was formed, consisting of Capt. Portlock, Mr. R. Ball, Mr. W. Thompson, Dr. Coulter, Mr. W. A. Eyton, and Mr. Vigors, who was requested to act as Secretary to the Committee.

Mr. J. E. Gray and Mr. R. Ball were requested to investigate the mode by which Mollusca, Annelida, and other marine Invertebrata excavate rocks.

Capt. Ducane, R.N., was requested to continue his researches concerning the Crustacea of the waters of Southampton.

For the purpose of experiments on the Growth of Plants in Glass Vessels, on Mr. Ward's plan, the further sum of 50*l.* was placed at the disposal of a Committee, consisting of Mr. James Yates, Dr. Daubeny, Prof. Henslow, and Mr. R. Ball.

For the purpose of experimenting on the best modes of Preserving Animal and Vegetable Substances the sum of 25*l.* was placed at the disposal of a Committee, consisting of Prof. Henslow, Mr. Jenyns, Dr. Clark, and Prof. Cumming.

MEDICAL SCIENCE.

The following Committees were re-appointed:

For investigating the Anatomical Relations of the Absorbent and Venous Systems in different classes of Animals, with 50*l.* at their disposal; for inquiring into the Effects of Poisons on the Animal Economy, with 25*l.* at their disposal; for the Chemical

Analysis of the Animal Secretions, with 25*l.* at their disposal *; for investigating the Pathology of the Brain and Nervous System, with 25*l.* at their disposal; for investigating the Sounds of the Heart, the Committees of London and Dublin, with 25*l.* at the disposal of each.

A Committee was appointed, to consist of Dr. Carson and other Members of the Association resident in Liverpool and Manchester, for the purpose of making experiments on the Lower Animals labouring under Diseases of the Lungs, to determine the influence of local or general remedial means in the Cure of these Diseases, with 25*l.* at the disposal of the Committee.

A Committee was appointed, to consist of Dr. Williams and other Members of the Association, to investigate the Physiology of the Lungs and Bronchi.

STATISTICS.

In furtherance of inquiries into the actual State of Schools in England, considered merely as to numerical analysis, the further sum of 150*l.* was placed at the disposal of a Committee consisting of Lord Sandon, Lieut.-Col. Sykes, and Mr. G. R. Porter.

In furtherance of inquiries into the Condition of the Working Population, specified in the form of numerical tables, the sum of 100*l.* was placed at the disposal of a Committee, consisting of Lord Sandon, Lieut.-Col. Sykes, and Mr. G. R. Porter.

For the purpose of drawing up instructions for the Advancement of Statistical Science a Committee was appointed, consisting of Lord Sandon, Col. Sykes, Mr. Porter, Mr. W. Langton, Mr. W. R. Greg, and Mr. J. Heywood, with power to add to their number.

MECHANICAL SCIENCE.

For the prosecution of experiments on the Strength of Cast Iron, produced by the application of the Hot and the Cold Blast, and the extension of the same to Wrought Iron, the Committee, originally composed of Mr. E. Hodgkinson and Mr. W. Fairbairn, was enlarged by the addition of Prof. Willis, Mr. Donkin, and Mr. P. Clare, with 100*l.* at their disposal.

For procuring, printing, and circulating periodical statements

* Mr. Golding Bird was added to this Committee.

of the *Duties* of Steam Engines in Cornwall and elsewhere, the grant of 50*l.*, at the disposal of Mr. J. Taylor, was renewed.

For ascertaining the Amount of Duty actually performed by the consumption of one bushel of Coals in Steam-Engines employed in pumping Water, not in the Cornish districts, a Committee was appointed, consisting of Mr. Bryan Donkin, Mr. G. H. Palmer, Mr. James Simpson, Mr. John Taylor, and Mr. Thomas Webster, who was requested to act as Secretary, with 100*l.* at their disposal.

The Committee was requested to report all the circumstances affecting the Amount of Duty in each case.

For instituting a series of experiments to determine the mean Value of Railway Constants, a Committee was appointed, consisting of Mr. Hardman Earle, Dr. Lardner, Mr. Joseph Locke, Mr. G. Rennie, and Mr. John MacNeil, with 50*l.* at their disposal.

For obtaining a series of observations on the average locomotive *Duty* of a ton of coals per horse-power in Steam Vessels, a Committee was appointed, consisting of Mr. Fairbairn, Dr. Lardner, Mr. J. S. Russell, and Mr. J. Taylor, with 100*l.* at their disposal.

The Committee was requested to report all the circumstances, nautical and mechanical, which may affect this *Duty*.

Should the Committee above named find it expedient to extend their researches to the other side of the Atlantic, the further sum of 50*l.* was placed at their disposal for such purpose.

ARTS.

A Committee was appointed to superintend the exhibition of Mechanical Inventions, Manufactured Articles, and Processes in the Arts at Newcastle; viz. Sir D. Brewster, Mr. Babbage, Prof. Wheatstone, Prof. Willis, Prof. Powell, and Prof. Johnston, who was requested to act as Secretary.

GENERAL REMARKS.

In grants of money to the Committees for purposes of science, the Member first named is empowered to draw on the Treasurer for such sums as may from time to time be required. The General Committee does not contemplate in these grants the payment of personal expenses to the Members.

SYNOPSIS OF SUMS APPROPRIATED TO SCIENTIFIC OBJECTS.

BY THE GENERAL COMMITTEE AT THE LIVERPOOL MEETING.

(Drawn up for comparison with vol. iv. p. xl. and vol. v. p. xx.)

Reduction of Observations on Stars (vol. iv. p. xv.; vol. vi. p. xvii.)	£500	0
Continuation of Tide Discussions at Bristol (vol. v. p. xx.; vol. vi. p. xvii.)	75	0
Meteorological Instruments and Subterranean Temperature (vol. iv. p. xix.)	100	0
Comparative Level of Land and Sea (vol. iv. p. xxvi.; vol. v. p. xvii., part of the former grant renewed)	272	0
Lens of Rock Salt (vol. iv. p. xxii.)	80	0
Hourly Observations in Meteorology (vol. v. p. xvi.)	50	0
Investigations on the Form of Waves (vol. v. p. xvi.)	100	0
*Astronomical Society's Catalogue (vol. vi. p. xvii.)	500	0
*Action of Gases on Solar Spectrum (vol. vi. p. xviii.)	100	0
*Osler's Anemometer (vol. vi. p. xviii.)	40	0
*Repairs of an Anemometer (vol. vi. p. xviii.)	10	0
Composition of Atmospheric Air (vol. v. p. xvii.)	20	0
Chemical Constants (vol. iv. p. xxiv.)	30	0
*Effect of Water on Cast and Wrought Iron (vol. vi. p. xix.)	20	0
*Effect of Heat of 212° on Organic and Inorganic Bodies (vol. vi. p. xix.)	10	0
Mud in Rivers (vol. iv. p. xxvii.)	20	0
Fossil Ichthyology (vol. iv. p. xxvii.)	105	0
Peat Mosses in Ireland (vol. v. p. xviii.)	50	0
Growth of Plants under Glass (vol. v. p. xviii.)	50	0
*Preservation of Animal and Vegetable Substances (vol. vi. p. xx.)	25	0
Absorbents and Veins (vol. iv. p. xxxi.)	50	0
Sounds of the Heart (vol. iv. p. xxxi.)	50	0
Effects of Poisons on the Animal Economy (vol. iv. p. xxxi.)	25	0
Pathology of Brain and Nervous System (vol. iv. p. xxxii.)	25	0
Chemical Analysis of Animal Secretions (vol. v. p. xix.)	25	0
*Disorders of the Lungs (vol. vi. p. xxi.)	25	0
Carried forward	£2357	0

Brought over. . .	£2357	0
State of Schools in England (vol. v. p. xix.)	150	0
*Condition of Working Population (vol. vi. p. xxi.) .	100	0
Strength of Iron (vol. iv. p. xxxii.; vol. vi. p. xxi.)	100	0
Duty of Cornish Engines (vol. iv. p. xxxii.)	50	0
*Duty of Pumping-Engines not in Cornwall (vol. vi. p. xxii.)	100	0
*Railway Constants (vol. vi. p. xxii.)	50	0
*Duty of Steam Engines in Vessels (vol. vi. p. xxii.).	100	0
*Conditional Grant to ditto (vol. vi. p. xxii.) . . .	50	0
Total of Grants	£3057	0

The Grants to which the asterisk (*) is prefixed relate to subjects for which no previous Grant has been made. The others are renewals or continuations of former Grants.

ADDRESS

BY

PROFESSOR TRAILL, M.D.

GENTLEMEN,—The duty of addressing the British Association, on this occasion, was originally confided to one admirably qualified to do justice to the task; and few persons have more cause to lament the circumstances which deprive us of the services of that gentleman than the individual who now addresses you. To those who know me only as connected with my present domicile, my position at this Meeting may appear unwarrantable or presumptuous. I can only plead, that though highly honoured by the office, it certainly was neither expected nor solicited by me; and that, unless twenty-eight years' residence in this place, and the existence of numerous and valued local attachments, may be considered as conferring the privilege, I fear I can advance few claims to be received as one of the Secretaries for Liverpool.

The objects and nature of the British Association for the Advancement of Science have been so eloquently handled by my predecessors, that to some members the subject may appear to be exhausted; but, as the Association is necessarily a fluctuating body—as many have now joined it for the first time—and as there still seems to be considerable misapprehension in the public mind regarding its objects and utility, a few remarks on the purposes which it is intended to accomplish may not be altogether misplaced.

The British Association was undoubtedly suggested by the successful efforts of the philosophers of Germany, within the last few years. The obstacles to free intercourse between scientific men, in that part of Europe, had always been felt as a great bar to the advance of science. Under such a system, those who, in sequestered regions, had long pursued laborious investigations, had often the mortification to discover that they were following paths trodden by others, or in which they had been completely anticipated by more fortunate inquirers. To obviate such grave inconveniences, and to promote social intercourse among men of science, scattered over wide regions, separated by physical and

political obstacles, though connected by one common tongue, were the objects of that great Continental Association; and that these have been, to a considerable extent, realized by the annual assemblages of the illustrious sons of Germany, is generally admitted.

In our more united and highly-favoured land, the facilities of intercourse between its most distant points, the less isolated position of our philosophers, unquestionably render the progress of science less dependent on such general associations of its cultivators than in Germany: yet it has never been doubted, that the personal intercourse of men engaged in similar pursuits is favourable to the progress of philosophical investigations, by the direct assistance derived from the experience and suggestions of others, and by fostering that generous emulation in the search after truth which imparts a wholesome stimulus to mental exertion, while it tends to smooth the asperities occasionally engendered by controversy, even in the abstract sciences. Men accustomed to meet and act together for one great end, naturally and insensibly imbibe the social spirit—scientific jealousy and personal rivalry are softened by mutual approximations; and individuals composing the Association, like members of the same family, learn to temper the pursuit of personal distinction by an honest exultation in whatever redounds to the honour and celebrity of the body to which they belong.

These advantages the British Association shares in common with many other societies; but it possesses characteristics peculiarly its own. It can scarcely reckon a period of infancy;—it sprung at once from the conception of its founders, like Pallas from the head of Jove, in the perfection of youthful vigour—secure in the panoply of rectitude of purpose against open or secret hostility. It quickly numbered in its ranks the *élite* of the philosophy of the United Kingdom; and, strengthened by the accession of foreign associates of distinguished reputation, it has extended its views beyond its original horizon, and has attained a colossal magnitude that distinguishes it above every other scientific association in the British empire.

This Institution ought not to be considered as the rival of any of the previously existing philosophical establishments which give lustre to these kingdoms. It, indeed, receives communications on every branch of scientific inquiry, but it professes to publish none of the numerous contributions which have given rise to the interesting and animated discussions in its different Sections: a short abstract of these papers is all that it attempts to promulgate; but the distinguishing features of its publications are those invaluable Reports on the pro-

gress of science which the Association has confided to some of its members, especially selected for that important duty.

The advantages thus conferred on general science will be best appreciated by persons whose studies are directed to any of the subjects discussed in the Reports, and who have once felt the want of an accurate analysis of what had been recently added to our previous stock of knowledge; but it would be impossible to calculate in how many instances those abstracts of precise and useful information have saved the time, and abridged the labour, of the retired student, in tracks already explored by other philosophers. Another peculiarity in the publications of the Association consists in the circulation of *desiderata* in different branches of science. The attention of their cultivators, thus drawn to the principal deficiencies in each, has already filled up various chasms in the paths of intellectual exertion, and stimulated to inquiries that cannot fail to lead to important results.

It soon became apparent that the British Association must exercise a powerful influence on the general diffusion of science, and could undertake, or materially promote, investigations to which individual research and unaided exertion are utterly inadequate. Its annual migrations, and the comparative ease of admission into its ranks, have unquestionably increased the taste for scientific disquisition; and, although it would be absurd to suppose that all who seek for enrolment in the Association are destined to extend the boundaries of science, who can believe that familiarizing large masses of the community with such investivations, and exhibiting how the highest branches of philosophy may be made available to the purposes of life, will fail to promote the avowed purpose of our meetings? Who will venture to deny, that the contemplation of the galaxy of illustrious men, mustered on occasions similar to the present, has often proved the first impulse to the secret aspirant after honourable distinction—has afforded the *Promethean spark*, that kindled the sacred flame in the breast of slumbering genius?

The Association has not failed to use its influence in stimulating our rulers to aid the progress of science. At its instigation, the British government has taken up the task of the reduction of the enormous mass of observations on the heavenly bodies, accumulated since 1750 at the Greenwich Observatory—which, though collected at a great expense to the nation, and by the exertion of consummate skill in the observers—which, though pronounced by the highest authorities in Europe to be of the utmost moment to the future progress of astronomy,—have been permitted to remain a rich,

but unexplored, mine of facts. The voice of our petition has been heard—the work has been auspiciously begun—and 500*l.* have been assigned by the Treasury for the commencement of this great national work.

The subject of the Tides, so strangely neglected in this great maritime country, from the period of the promulgation of the Newtonian Theory to our own times, has engaged the attention of the Association from its commencement. The advances which have recently been made on this subject, and which have greatly altered the aspect of that branch of science, had chiefly for their original basis the very valuable tide observations made in this port, many years ago, by Mr. Hutchinson, a dock-master, embracing an interval of above thirty years. The originals are preserved in the Lyceum Library of Liverpool; and, by the liberality of the proprietors, have been confided to the hands of Mr. Lubbock, under whose direction the discussion of them, ordered by the Association, has thrown a new light on the laws of Tidal phenomena.

Since that time, the earnest representations of a distinguished Associate, whom this county claims as a native, have given rise to a most important set of observations on the tides. Mr. Whewell, by personal application to the chief of the coast-guard service, and solicitation to the Admiralty, has procured the completion of a continuous series of observations, at upwards of 500 stations, along the coasts of Great Britain and Ireland. They were continued for a fortnight in June 1834, and again in June 1835, when they were extended from the mouths of the Mississippi to the northern extremity of Europe. These observations have been *discussed* at the expense of the Admiralty; but, as I shall presently mention, the Association has voted a large sum to be applied by Mr. Lubbock to the same object.

These discussions have, within the last few years, led to very curious results; for instance, to the fact of *the rise of the mean level of the tides, in proportion to the fall of the barometer, and the existence of a diurnal tide*—i. e. the difference between the morning and evening tides of the same day. This diurnal tide, it may be interesting for the inhabitants of Liverpool to know, was first marked in the tide tables constructed by a young ingenious townsman, Mr. Bywater, jun., who has, unfortunately for science, died since the last Meeting of the Association.

The importance of the subject, and the success already obtained, have encouraged the Association to direct the discussion of the Tidal observations recorded at the port of Bristol, and at the London Docks; and to supply the means of defraying the necessary expense.

The influence of researches on tidal waters to navigation and to com-

merce are too obvious to require illustration: but perhaps it may not be unsuitable, in this place, to refer to the deductions of our eminent associate, Captain Denham, on the capability of the Mersey "to command a navigable avenue to the ocean, so long as its guardians preserve the high-water boundaries from artificial contraction." It may also be stated, that in our Transactions, this gentleman has recorded his most important general inference (drawn from a connected series of observations on the tides, which the liberality of the Dock Trustees of Liverpool enabled him to carry on)—*that there is one invariable mean height, common to neap and spring tides*—THE HALF TIDE MARK—a point from which engineers, geologists, and navigators will henceforward commence their calculations, and adjust their standards of comparison.

The Association made application soon after the meeting at Edinburgh for the resumption of the Trigonometrical Survey of Scotland; a work imperiously demanded by the imperfect state of our best maps and charts of that part of the island, either for the purposes of geology or navigation. It is needless to give further proof, than that parts of several of the large islands at the mouth of the Clyde are laid down several miles out of their true position. The magnificent scale on which the survey of Ireland is now carrying on, emboldened various scientific societies of Scotland this year to memorialize the government on the subject. I am happy to add, that the applications have been successful, and the triangulation of Scotland will recommence early in 1838.

The British Association may also boast, that at its instigation, our illustrious associate, Arago, moved the Bureau des Longitudes to solicit from the French government the publication of the series of observations on the tides at Brest, and a reduction of the astronomical observations made at the École Militaire. The Brest observations have been printed, and a copy of the valuable documents put in the hands of one well able to appreciate them.

At the Dublin meeting, a committee was appointed for representing to our own government two objects important to science; which can only be accomplished in a satisfactory manner by the rulers of a powerful nation, or by an union of governments in the cause of philosophy. The first related to the establishment of Magnetical and Meteorological Observatories, in different parts of the earth, furnished with proper instruments, and in which the observations should be conducted on acknowledged and uniform principles. The extent, and the variety of climate of the British possessions, indicate them as favourable points for such establishments, which have already been commenced in France and its dependencies, and may hereafter, by the co-operation of the

several governments of Europe, and of our Trans-Atlantic brethren, be extended over a large portion of the civilized world. The second suggestion was the importance of an Antarctic Expedition, for prosecuting discoveries and observations in Geography, Hydrography, Natural History, and, above all, Magnetism, with a view to determine the positive southern magnetic pole or poles, and the direction and intensity of the magnetic force in antarctic regions. The East India Company was likewise to be requested to favour the same objects, especially at their establishment at Madras.

The General Committee some time ago made application to the authorities, both in France and this country, respecting some mode of instituting a reciprocal protection to literary property. Might I venture here to allude to a recommendation which I hope the Association will not fail to leave in Liverpool, for the promotion of a scientific object of immense consequence to this port—the establishment of an Observatory in or near Liverpool? The adoption of such suggestions, while conferring an incalculable benefit on science, would rear a proud, imperishable, and bloodless monument to national greatness.

These statements might be a sufficient answer to a question, sometimes put in tones of captious sarcasm,—What has the Association directly contributed to the progress of useful knowledge? Without again appealing to the very admirable reports on the progress of science published in our Transactions; without again claiming merit for the suggestions and efforts already noticed,—I should fearlessly answer such cavillers, by an appeal to the value and number of the communications, which have occupied the different Sections, at each annual meeting, and which contain the application of pure science to important questions in Physics, or of experimental investigation to numerous branches of knowledge. I would point to the valuable researches which have been undertaken and completed at the request of the Association, among which it may be permitted to indicate the following memoirs:—The comparison of the standards of Linear Measure, made by the late Mr. Troughton, for the town of Aberdeen, and the Astronomical Society of London, which were confided to Mr. Baily—a comparison of much consequence, as the *standard yard*, by the same artist, was lost in the fire which consumed both Houses of Parliament; On the Investigation of the Impact upon Beams, when struck by bodies of different weight, hardness, and elasticity, by Mr. Hodgkinson; On the Direction and Intensity of the Magnetic Force in England, Ireland, and Scotland, by Professor Lloyd, Major Sabine, and Captain James Ross; On the influence of Height above the Sea on Magnetic Intensity,

by Professor Forbes—from which it appears that the horizontal intensity diminishes $\frac{1}{1000}$ of the whole, for every 3000 feet of vertical ascent; On the quantity of Rain falling at different heights above the surface of the Ground, made at York, by Professor Phillips, and Mr. Gray; On the determination of the mass of the planet Jupiter, by the Astronomer Royal; On the Horary Variations of the Barometer, Thermometer, Hygrometer, and Whewell's Anemometer, by Mr. Snow Harris—part of which has already appeared, and of which the sequel will be laid before this annual Meeting; On the Duty performed by Cornish Steam Engines, by Mr. Enys; On the Ratio of the Resistance of Fluids to the Velocity of Waves, by Mr. Russell and Mr. Robison—of which we expect to receive an account on this occasion.

We may also be permitted here to allude to some highly-interesting investigations, still in progress, under the auspices of the Association, such as—Observations on the Temperature of Springs and Deep Mines, by Instruments procured and verified by the Meteorological Council, which are already placed in various districts of Great Britain and Ireland, and also in Peru, under the direction of our scientific associate, Mr. Pentland, from which results most interesting to Geology are anticipated; On the Temperature of the strata at different depths near Edinburgh, by Professor Forbes, for ascertaining the rate of the transmission of Solar Heat downwards; A continuation of Mr. W. Vernon Harcourt's experiments on the effects of long-continued Heat on Rocks and other bodies; Experimental Investigations into the Fabrication of Glass, by the same gentleman and Dr. Faraday; A Systematic Catalogue of all the Organized Fossils of the British Islands, by Professor Phillips; An Experimental Determination of the Strength and other Mechanical Properties of Iron obtained by the Hot and Cold Blasts, undertaken by Messrs. Hodgkinson and Fairbairn; Analysis of Iron in the different stages of its manufacture, and an Extension of the Tables of Chemical Constants, by Professor Johnston; Statistical Returns of the State of Education in our great towns; An Examination of the Statistical documents preserved in the India House, by Professor Jones; besides the discussion of numerous very interesting contested points in Natural History and in Medicine.

These are satisfactory evidences of the activity of the Association; but it has not scrupled also to afford pecuniary assistance, when such aid appeared requisite to ensure success. It is true, that the moderate sum, payable on admission into the Society, seems more suited to the finances of the majority of philosophers, than to the support of ex-

tensive enterprises; yet the numbers annually desirous of admission supply funds, adequate to important undertakings; and the power thus given to the General Committee is acknowledged to have been exercised with a sound discretion.

Without descending to minute particulars, it may be well to state some of the appropriations for various scientific inquiries.

The application to the French government already noticed, was accompanied by a vote of the General Committee of the Association to appropriate 500*l.* for a duplicate reduction of the Astronomical Observations, with a view to secure the utmost accuracy in these important computations. This offer proves the value attached by the Association to whatever can improve Astronomy, and the zeal which carries its scientific views even beyond the limits of the British Empire. This sum is still devoted to the reduction of Astronomical Observations. 70*l.* have been devoted to the determination of a constant numerical expression for Lunar Notation, as deduced from the observations made with the Greenwich mural circle: 250*l.* have been appropriated for the Discussion of the Tides; besides 150*l.* voted last year for the Discussion of the Observations made on Tides at Bristol: 100*l.* were set apart for meteorological instruments, and experiments on subterranean temperature,—the last a problem of the highest interest to Geology, as involving the question whether or not there be a general source of terrestrial heat, independent of solar influence: 500*l.* have been voted for ascertaining the permanence or fluctuation in the relative level of the land and of the ocean, on the coasts of the British Isles. This subject affords matter for the highest speculations in Geology; but it is doubly interesting to a maritime people, as affecting the permanence of our river navigation, and of our naval stations: 210*l.* were given to enable M. Agassiz to include the fossil fishes of our islands among his interesting Researches on Fossil Ichthyology, a publication which forms a new era in this department of Geology: 100*l.* have been assigned for Investigations on the Form of Waves, and the mode of their production: 150*l.* for the experiments on Vitrification, and the improvement of the manufacture of Glass: 80*l.* for experiments on Lenses of Rock Salt; a subject of much interest to Optics: 50*l.* for determining the specific gravity of Gases: 60*l.* for an experimental inquiry into the strength of Iron: 50*l.* for ascertaining the Duty of Steam Engines: 50*l.* for an inquiry into the Origin of Peat Mosses: 250*l.* for conducting various Physiological Rearches: 150*l.* have likewise been voted for investigating the Statistics of Education in our large towns. While

on this subject, I must not omit to state that the Statistical Societies of London and Manchester trace their origin to this Association; and that the laborious investigations of Colonel Sykes, on the Statistics of India, founded on materials chiefly collected by himself, and undertaken at the request of the Association, are now happily brought to a close, and will be presented to the Association.

These appropriations are exclusive of several minor sums devoted to the encouragement of investigations into various branches of Physics, Chemistry, and Natural History; making an aggregate of upwards of *2659l.* set apart from the funds of the Association, in the past year, for scientific objects—a larger sum than has been appropriated, in so short a period, by any other Society, to purposes purely scientific.

While stating these facts, we ought not to conceal a circumstance, creditable to the disinterested zeal for the cause of science elicited by these grants. Though the votes have been liberal, this circumstance has never induced inconsiderate expenditure. In many instances, far less than the sums appropriated have been actually expended; and in various instances, the individuals intrusted with the funds have refused to draw on the Association, when their own labour could save its finances.

It has been usually considered a part of the duty of the Local Secretary, to give a short account of the Reports which are just published.

The first in the volume is the masterly report 'On Mineral and Thermal Waters,' by Dr. Daubeny. After glancing at the nature of atmospheric water, the author has pointed out the connexion of the foreign ingredients, detected in the atmosphere, with the production of meteoric stones, the formation of nitric acid under certain circumstances, and the presence of the organic principle found in air, even when collected on great elevations, to which the name of Pyrrhine has been given. He considers the existence of the elements of meteoric stones in the atmosphere as doubtful. The nitric acid may sometimes arise from the effects of electric explosion on its oxygen and nitrogen; at other times this union is seemingly produced by causes not yet ascertained. The researches of the celebrated Ehrenberg have shown, that pyrrhine probably owes its origin to the ova of polygastric *infusoria*, raised by evaporation and by atmospheric currents induced by changes of temperature. In considering the ocean, the author directs particular attention to its gaseous contents; as confirming or invalidating the opinion of Arago, that oxygen predominates in all waters, even to considerable depths. This law is well known to hold good in the more superficial portions of the ocean, and seems intended to support the respiration of aquatic animals; but the preponderance of oxygen at

great depths cannot yet be considered as absolutely determined, on account of the imperfection of the modes of obtaining unmixed water from such points. The water of springs is more especially the object of Dr. Daubeny's Report.

In considering the saline contents of mineral springs, he gives some ingenious speculations on the origin of these salts; especially of the carbonate of soda, of the sulphates, and of boracic acid. The common salt he derives from the same source as the saltness of the sea; and he considers rock-salt as a deposition from the waters of the ocean; a view confirmed by the presence in saline deposits of iodine and bromine—elements first detected in marine productions. Dr. Daubeny regards the absence of these two bodies in the lowest and purest bed of the Cheshire rock-salt while they abound in the upper saliferous beds, as proofs that rock-salt was deposited from a saturated solution. The salts of iodine and bromine, as well as the earthy muriates, from their greater solubility, would remain longer in solution; and thus be mingled with the more hasty mechanical deposits from the waters. The brine springs of Droitwich, which are found to contain neither iodine nor bromine, he also considers as derived from a salt deposited from a saturated solution.

The siliceous earth, so often detected in thermal springs, he conceives to be dissolved by alkaline matter, aided by a high temperature. Both alkali and silica may be afforded by felspathic rocks; and Dr. Daubeny conjectures, that silica may be more soluble in hot water at the moment of its separation from its combinations in the rock, or ere it has its aggregation increased, by assuming the crystalline texture. He states, that it may be interesting to try, whether hot water has a stronger action on such bodies as opal, in which the molecules do not seem to have a true crystalline arrangement, than on quartz. Since I came this time to Liverpool, I subjected a fragment of wood-opal for fourteen days to a temperature estimated about 280° Faht., in the boiler of a fixed steam-engine; but it had neither lost nor gained the smallest weight in that time.

The author combats the opinion of Anglada on the origin of the organic matter termed *Glairine*, now found to be a very common ingredient of thermal springs. This substance Anglada supposes, with little probability, to be derived from the interior of the earth; while the observations of our author on this substance, as collected from above fifty springs, especially from the thermal sources of the Pyrenees, show, that *Glairine* is probably derived from the decomposition of organic bodies, such as *confervæ* and infusory animalcules.

The author's speculations on the source of the heat of thermal springs, partake of his views on the origin of volcanoes; namely, that it depends on the penetration of water, through fissures in the external crust of the globe, to the regions where he conceives the elements of earthy and alkaline bodies to exist: that the intense heat, generated during the oxidation of these elements, converts a portion of the water into steam; which, under compression, obtains a high temperature, acts on various earthy bodies, and communicates its heat to subterranean waters which issue in thermal springs. This view he supports by numerous instances observed by geologists; especially by Professor Forbes in the Pyrenees, where thermal waters gush out in the vicinity of disruptions, or upheavings of strata by ignigenous rocks. The author believes that, unless in countries agitated by volcanic action, the temperature of thermal springs is subject to little variation; and that, where the contrary has been alleged, it may generally be ascribed to the imperfection of the thermometers employed.

The temperature of copious springs has generally been observed to vary little, and is about the mean temperature of the country where they occur. Thus the magnificent fountain at Vaucluse has the mean temperature of that part of France, and scarcely ever varies one degree of Reaumur. It is, however, worthy of remark, that I found the temperature of St. Winifred's Well, the largest spring in Britain, by different observations during twenty years, to experience variations of more than four degrees of Faht., always to have a temperature several degrees above the mean of Flintshire, and at all seasons superior to that of another very large spring, Fynnon asa, about five miles distant. The variations may perhaps arise from surface water, directly finding its way into the Holywell spring; but its constant superior temperature may be accounted for, on Dr. Daubeny's principle, from the disturbances in the strata produced by the numerous mineral veins in the adjacent Halkin Mountains.

The second report is 'On the Direction and Intensity of Terrestrial Magnetism in Scotland,' by Major Sabine.

The experiments were made at numerous stations, both by the statical method of Professor Lloyd, in which the dip and intensity are ascertained by the same instrument, and by Hansteen's method, of measuring intensity by the number of horizontal vibrations in a given time. It is interesting to know, that the intensities estimated by both methods nearly correspond; and that we therefore may place confidence in either mode of observing, when allowance is made for changes in the force of magnetism in the needles employed. Major Sabine experienced, on

several occasions, what has been remarked by other observers, that magnetical experiments are liable to be affected by the vicinity of Trap rocks. This was particularly noticed by him at Oban and Loch Scavig, so as to render his observations at the latter of no utility for his calculations. Two of the most familiar examples of this quality of ignigenous rocks are afforded by the powerful effect of a column of the Giant's Causeway, as mentioned by Professor Lloyd ; and by the strong polarity of the basaltic cap of Arthur's Seat, near Edinburgh, which is capable, in more positions than one, of causing complete inversion of poles of the pocket compass. These instances show how carefully the vicinity of considerable masses of Trap rocks should hereafter be avoided, in all delicate experiments on magnetic dip and intensity : for the errors they occasion may be more considerable than the effect of a ship's local attraction on azimuths, and are far less easily compensated.

Major Sabine has considered it best to give no other designation, on his chart, to the isodynamic lines in Scotland, than what expresses their relation to each other, until we have more fully investigated their relation to magnetic intensity in England. The differences between the deductions, in regard to the Isodynamic lines in Scotland and in Ireland, are very considerable, and apparently too great to be due to any difference in the lines themselves: but future observations will probably disclose the cause.

In a former volume of our Transactions, appeared a valuable report on North American Geology: in that just announced is an excellent essay on the Zoology of that portion of the globe, by Dr. Richardson, the intrepid friend and companion of Sir John Franklin, in their hazardous exploratory expeditions to the shores of the Arctic Ocean. After some general remarks on the climate of North America, he presents us with an extensive Table of Mean Temperatures, calculated for periods of six and three months throughout the year, for the hottest and the coldest months, and for the months with a mean temperature above 52° Faht., taken at forty-four different stations, and collected from his own and Franklin's observations, combined with those of Humboldt, Ross, Parry, and Scoresby. The results are very important, and show, in a striking manner, the very erroneous deductions on the mean temperature of any place, if investigated by Mayer's formula, especially in very low or very high latitudes.

The geographical position of Mexico constitutes the point at which the Faunæ of the northern and southern regions meet; and hence it is the place in which the general laws regulating the distribution of animals can be most satisfactorily studied. There the Wolf of a northern cli-

mate is seen with the Monkey of tropical regions; the Bunting and the Titmouse nestle near the Parrot and the Trogon; the Phalarope of the North seeks its food on the same beach as the Jacana and the Boatbill of Brazil.

Dr. Richardson states, that though colonization has, in America, restricted the range and modified the migrations of wild animals, we have no evidence that a single species has been there lost within the records of history. The Quadrumana, or Monkeys, of America are peculiar to that continent. None of them have what may be called a perfect hand, with the thumb opposed to the fingers. Their thumbs are small, sometimes only rudimentary, or even wholly wanting. Not a single Ape—not one true Baboon is to be found among them; but many are furnished with prehensile tails, admirably adapted for animals moving among thick forests, and almost as serviceable for grasping as the proboscis of the Elephant.

Almost all the Mammifera, considered as common to the New and Old Worlds, belong to the order of Carnivora; yet it is by no means improbable, that a minute examination of species now considered as the same, may detect specific differences among them. I would particularly recommend attention to the skulls of animals. My late ingenious young friend, Robert Jameson, of Edinburgh, had acquired great tact in discriminating the Carnivora, in particular, by the form and position of the sutures uniting the bones of the face, which differ much in each species. It is believed by many naturalists, that the proportions of the skulls of Indian birds, in other respects similar to our own, as compared to their bodies, differ from those of Europe. Similar differences may occur in other parts of the skeletons of quadrupeds, which have escaped the superficial examiner, yet sufficient to constitute specific characters. This would be particularly valuable in determining the species of weasels and amphibious Carnivora, which, at present, are very perplexing to the naturalist.

All the existing *Marsupial* animals are confined to America, Australia, and some other South Sea Islands: yet, at one period, animals of this order must have been very generally distributed over the earth, as their bones occur everywhere in a fossil state, and are formed in the oldest deposits of mammiferous remains.

The number of *Rodentia* in North America is great, and all seem to be peculiar to the New World: of the Edentata, one only is found in North America. Two or three species occur in Africa and India; all the rest are South American. It is singular, that of the existing Pachydermata, two species only are considered as indigenous to Ame-

rica—the tapir and the peccary; and of these, the last only is found in North America. Yet no region can boast of more numerous, or more gigantic species of fossil animals of this order—as elephants and mastodons—and, what is remarkable, though the present race of horses is acknowledged to be not indigenous, fossil bones of the horse were found on the N.W. coast by Capt. Beechey mingled with those of elephants. Of the *Ruminantia*, two only seem to be common to the Old and New World—the reindeer and the elk—unless we admit that the argali of Siberia is the same as the sheep of the Rocky Mountains.

The *Cetacea*, as might be expected from their mode of life, may be considered as common to both worlds. The *Rytina Borealis* and *Manatus Americanus* are found in North America, but not in the seas of Europe. Temminck estimates that we have 930 well ascertained, and 140 doubtful species of Mammifera; of these 207 are in the New World, and 169 in North America. The birds of North America are most numerous, and have been illustrated by the successive labours of Pennant, Wilson, the Prince of Musignano; but, above all, in the Fauna Boreali-Americana of Richardson and Swainson, and the superb work of Audubon. The similarity between the birds of Europe and North America is marked by one third of the species being common to both Faunæ. These are chiefly to be found among the Grallatores and Natatores, two-thirds of which orders are common to both: of the order Rapaces several are common to both continents. The Insessores are very numerous, and a great number are peculiar to America. The Rasores, in all countries, are little disposed to migrate; and almost all of this order found in America are peculiar to it, with the exception of some pigeons and a few Arctic grouse.

The Reptilia of North America are exceedingly numerous. All, with the exception of some sea-turtle, are distinct from those of the Old World. Two genera equally fitted to live in water and in air, as possessing both gills and lungs, and represented by the *Siren lacertina* and *Menopoma gigantea*, which abound in North America, have only one analogous animal in the Old World, the *Proteus anguinus* of the lakes and caves of Carniola.

Many species of the fishes of the American seas are found elsewhere; but the only fresh-water fish, common to both worlds, appears to be the pike; yet it is singular, that it does not occur in the waters to the west of the Rocky Mountains, although there the two continents are more approximated. Some of the family of the Salmonidæ and Clupiadæ, which visit America, have much resemblance to those of Europe.

This Report is an excellent specimen of the method of comparing the Faunæ of distant regions, and presents a model of a philosophical disquisition on the geographical distribution of animals.

The Association has, at different times, received three able Reports from Professor Challis, of Cambridge, on the Mathematical Theory of Fluids. In the first he showed how the application of mathematical analysis to investigating the properties of an imaginary fluid, supposed incompressible, or so compressible that the density should always be proportional to the pressure it sustains, admits of comparison with facts observed in the equilibrium and motion of water, or in the existing mechanical qualities of air. In the second, the author considered the modifications which these theories had, in later times, sustained by the introduction of certain molecular hypotheses on the constitution of matter, and how a comparison of the consequences of these hypothetical speculations with experimental results, served to establish the basis of the mathematical reasoning, and to make known properties and conditions of bodies not cognizable by our senses.

The present Report treats of several very important points in the Mechanical Theory of the Atmosphere. Mr. Atkinson's* attempt to ascertain the law of variation of temperature, at different heights in the atmosphere, would seem to require, for its establishment, a more extensive series of observations over a greater portion of the earth's surface than we now possess.

The difference between the velocity of sound, as determined by experiment, and Newton's deduction from Boyle's and Mariotte's law of elastic fluids, amounting to one-sixth of the whole, has given rise to many attempts to solve the problem, especially by Euler, Lagrange, and Laplace. The latter gave the true solution of the discrepancy—namely, that it arises from the evolution of heat, and its absorption, which accompany every sudden compression or expansion of air. The application of analysis, to afford a formula of correction, was first attempted by Biot and Laplace, and more lately by Ivory; but when we compare the theoretic deduction with the best experiments on the propagation of sound by Moll and Van Beck, at Utrecht, by Goldingham at Madras, and Parry and Foster in the Arctic regions, the slight discrepancies between experiment and calculation are more to be attributed to some imperfection in our formulæ than to error in experiments, which in their results agree so nearly, though made under very different circumstances.

* Trans. Royal Astron. Soc., vol. ii.

Under the head of Theories of Elastic Fluids, the author has introduced some valuable remarks upon the memoirs of Poisson, on the equilibrium and motion of elastic bodies, on the equilibrium of fluids, and the pressure of fluids in motion; and also on Laplace's theory of Capillary Attraction; for which I must refer to the Report.

We have next two reports on the Comparative Botany of Scotland and Ireland, by Mr. Mackay and Professor Graham, of Edinburgh. The first indicates the more remarkable plants that characterize the neighbourhood of Dublin and Edinburgh. In the second, Mr. Mackay points out the effect of climate on the Flora of Ireland. Ireland, it is true, has fewer species of plants than Great Britain, and possesses fewer alpine plants than Scotland. Its position and moister climate, however, put it in possession of many plants not found in Great Britain, but of species occurring in Spain and Portugal, among which may be noticed *Erica Mediterranea, Erica Mackiana, Pinguicola grandiflora, Arbutus unedo, Menziesia polyfolia.*

The Reports from the London and Dublin sub-committees on the Motions and Sounds of the Heart, in this and the last volume, will interest the physiologist and the physician. Ever since the application of the stethoscope, by Laennec, to the investigation of pectoral diseases, the sounds of the heart have been anxiously explored—its normal sounds studied, and its abnormal *bruits* eagerly inquired into, as important diagnostics of health and disease. The causes of those sounds have been matter of dispute; the investigation was recommended by the Association; and a sum appropriated for the expense of experiments on the subject. The Reports are the results of the labours of two sub-committees,who agree on the principal points,viz., that the first sound is produced during the systole, or contraction of the ventricles: and that the second sound is produced by the sudden check which the action of the semilunar valves gives to the current of blood impelled against them, by the elasticity of the arteries. In the second Dublin Reports, the abnormal sounds are illustrated by some ingeniously-devised experiments: but both sub-committees admit, that the motions and sounds of the heart require further investigations.

The Dublin Committee on the Pathology of the Brain and Nerves express their opinion, that to arrive at any accurate conclusions on so extensive and difficult a subject, a very large number of cases must be first submitted to examination, their symptoms during life accurately noted, and minute examinations instituted after death. One hundred and seventy-eight males and two hundred and ninety-four females, labouring under nervous affections, are in the Dublin House of In-

dustry and Hospitals—of whom forty-one have already been accurately examined, for the object just alluded to.

The results of the Discussion of the Observations on the Tides, obtained by means of the grants of the Association, have been reported by Mr. Lubbock.

Mr. Dessiou was employed to discuss the Tides observed at Liverpool, so as to ascertain the diurnal inequalities in their height, and also to classify the errors of prediction for a year in Liverpool and at the London Docks. The result is, that Daussy's deduction from the observations at Brest is confirmed, viz. that the height of high water is diminished when the barometer is high, and increased when it is low.

The various discussions of nineteen years of observations at the London Docks, amounting to 13,370, for the purpose of deducing the diurnal irregularities, and examining the effects of the moon's transit immediately preceding high water, and those of the two previous days, lead to the conclusion, that Bernouilli's theory of Equilibrium "satisfies the phenomena nearly, if not quite, within the limits of errors of the observations," and that it leaves very little to be otherwise accounted for.

A short statement is made by Professor Powell, of Oxford, on the Determination of Refractive Indices for the definite rays in the Solar Spectrum, from direct observation. The investigations recommended in the third Report of the Association have been commenced by Professor Powell, who continues his observations.

Dr. Hodgkin reported from the London Physiological Committee, that their investigations have not established the views of Lippi, respecting the communications of the absorbents with the veins; but they do not warrant a rejection of his observations, nor amount to any proof that the thoracic duct is the sole medium of communication between the lacteals and the veins. Direct communications between absorbents and veins have been observed by the reporter: but he is disposed to consider these as deviations from the normal structure.

A short Report on the best methods of ascertaining Subterranean Temperatures, and the proper form for Registers of such observations, is published by a Committee appointed for the purpose.

The last Report in the volume is the very profound Examination, by Sir William Hamilton, of the Validity of Mr. Jerrard's proposed method of *Transforming and Resolving the higher degrees of Equations*, as contained in his 'Mathematical Researches.' Mr. Jerrard's method may be characterized as consisting in rendering the problem indeter-

minate, and in employing this very property to decompose certain of the conditions into others, for the purpose of avoiding that elevation of degree, that would otherwise be the consequence of the elimination. The ingenuity of the principle, and the talent displayed in the researches, are freely admitted by Sir William, who contends that the process is valid, as a general and unexpected transformation of equations of elevated degrees, though it fails as a method of resolving them; and who thus sums up the result of his investigations on the subject:—"This method of *decomposition* has, however, conducted, in the hands of Mr. Jerrard, to *transformations* of equations, which must be considered as discoveries in algebra; and to the solution of an extensive class of problems in the analysis of *indeterminates*, which had not before been resolved: the *notation*, also, of *symmetric functions*, which has been employed by that mathematician in his published researches on these subjects, is one of great beauty and power."

On the very valuable matter contained in the proceedings of the Sections time will not permit me to enter, and I must refer you to the volume just published.

In conclusion, allow me, in the name of my respected colleagues and of our Liverpool associates, to offer a sincere and hearty welcome to the distinguished strangers whose presence confers additional interest to this meeting; and secondly, to congratulate the town of Liverpool on the exertions it has made, worthily to receive an Association, which, aiming at the diffusion of a general taste for scientific investigations, and their application to the improvement of society, seems calculated to perform an important part in the future destinies of our country—which, as co-operating with all other scientific bodies, and the rival of none, but including in its lists representatives from each—which, distinguished by the freedom of its discussions, the liberality of its assistance, and the importance of its recommendations, has been happily characterized, by an eloquent secretary of a former year, as a *Fourth Estate in the Realm*, and may be aptly designated HER MAJESTY'S PARLIAMENT OF SCIENCE.

Communications to the General Evening Meetings.

On Monday evening Professor Traill read his Address.

On Wednesday evening Mr. W. Snow Harris delivered a Lecture, illustrated by experiments on a large scale, on the application of Lightning Conductors to Ships.

On Friday evening Reports were received from the Presidents of Sections of the communications which had been read during the week.

On Saturday evening, besides the official business, the Predent noticed the gift, by Dr. Manni, of Rome, of a Colossal Bust of Mæcenas, as a mark of respect for the objects of the British Association. This magnificent Bust was forwarded for presentation to Dr. Bryce, of Liverpool, who has given the following account of the circumstances which render this Bust interesting to the public:—

"It was long a cause of wonder and regret, that no gem, medal, or statue of a man so illustrious had ever been discovered. At length, the Duke of Orleans, Regent of France, early in the last century, by a happy conjecture, fixed on one of the gems in his collection, an amethyst of small size, marked with the name of the engraver, Dioscorides, as being the representation of the head of Mæcenas. Another gem, bearing the name of Solon, the engraver, evidently representing the same person, was afterwards found in the Farnesian Museum; and a third of the same, a sardonyx, also engraved by Solon, has since been discovered in the collection of the Prince Ludovisi. The features given in these gems agree so well with all that has been handed down in the Roman Classics concerning the personal appearance and habits of Mæcenas, that the suggestion of the Duke of Orleans has been adopted by all subsequent antiquaries. A few years after the recognition of the head of Mæcenas on the gems of Dioscorides and Solon, both artists coeval with Augustus, an antique fresco painting was discovered in the ruins of the palace of the Cæsars on the Palatine Hill at Rome. This painting represents Augustus surrounded by his courtiers, conferring a crown on the Persian King Phraates, an event spoken of by Horace. In the front rank of the courtiers stands one, evidently the Prime Minister, in the act of speaking, whose features strongly resemble those on the gems of Mæcenas above described. Next to him is Agrippa, who is readily recognized from medals, coins, and statues of him. Horace also is found in the group. A copy of this painting was bought by Dr. Mead, and brought to England by him; and an engraving of it may be seen in Turnbull's Essay on Ancient Painting.

"This was the extent of antiquarian research and acquisition con-

cerning Mæcenas during the last half century, when, in the spring of 1830, a Bust was found in an excavation made by Professor Manni, at Carsoli, the ancient Carsuli, about seventy miles from Rome, on the Flaminian Way. This place is situated in what is esteemed the most beautiful and romantic district of the Roman territory, being near the cascades of the Nera, at Terni, and midway between the towns of Terni, Todi, and Spoleto.

"The Bust was of colossal size, the same as that presented to the Association, of pure Parian marble, and perfect in every feature. On being cleared of its incrustation, the modelling of the work was seen to be of that masculine firmness which characterizes the style of the epoch of Augustus, excelling in what is called a broad manner—the execution that of a master—with the greatest severity and grandeur; the emaciation by age of the individual represented being faithfully preserved. The striking resemblance of the Bust to the gems and picture of Mæcenas was at once recognized by the most eminent antiquaries and learned men at Rome.

"It may be interesting to state, in further confirmation of the high value which has been set upon the Bust, in Italy, as also because the circumstance enhances the gift of Professor Manni, that it has been twice copied by Thorwaldsen. One copy was presented to the Grand Duke of Tuscany, and by him placed in the Hall of the Academy of Petrarch, at Arezzo, as being the presumed birth-place of Mæcenas; the other to the King of Naples, who caused it to be deposited in the Borbonico Museum at Naples."

The following is an extract from the letter of Chevalier Manni, forwarded with the Bust to Dr. Bryce:—

"The town of Liverpool shall possess a third copy in marble. You will exhibit it at the Meeting of the British Association, and express my very great regret, that I shall not be able to be present, as I was last year at Bristol. You will say, that the friendly civilities, received on that and on other occasions in your country, moved me to offer some tribute of my gratitude and of my respect; and to manifest these feelings, I am delighted to place in your hands this Bust of Mæcenas."

In conformity with the wish of Dr. Manni and a rule of the Association, which provides that gifts of this nature to Meetings of the Association shall be transferred to some scientific institution or public body at the place where the Meeting is held, the Bust of Mæcenas will be placed in the Townhall, in Liverpool.

REPORTS

ON

THE STATE OF SCIENCE.

Report on the Variations of the Magnetic Intensity observed at different Points of the Earth's Surface. By Major EDWARD SABINE, *R.A., F.R.S.*

[With Plates.]

IT has been justly remarked by M. de Humboldt, "that the phænomena of the earth's magnetism, in its three forms of variation, dip, and intensity, have of late years been examined with great care, in the most different zones, by the united efforts of many travellers; and that there is scarcely any branch of the physical knowledge of the earth in which, in so small a number of years, so much has been gained towards an acquaintance with its laws, though not perhaps with its causes." (*Ann. der Physik,* vol. xv. p. 320.)

Be it here remarked, that it is to the example and the writings of this illustrious philosopher that the accelerated progress in this, as in so many other branches of physical science, is eminently due. His writings exhibit, in the most pleasing manner, the delightful, the never-failing interest which such pursuits afford, awaken thereby a taste for them in those who were previously unconscious of its existence, and stimulate its exercise in all. It is in this respect that M. de Humboldt has been not only a great promoter of science, but a moral benefactor to many; for it is the privilege of such pursuits that tedious hours are little known to the mind that engages in them, and the enjoyment which they yield is unimpaired by advancing years*.

M. de Humboldt's remark is particularly true in regard to the magnetic intensity. At the commencement of the present cen-

* The surviving friends of the late Major Rennell have, in their recollection of that true philosopher, when engaged in his latter years in his important work on the currents of the Atlantic Ocean, a memorable example of this power of physical research, to preserve its interest vivid and unbroken amidst the infirmities of declining years.

tury, the bare fact of there being any difference whatsoever in the intensity of the magnetic force in different parts of the earth was unattested by a single published observation. The maps attached to this memoir exhibit the progress which investigation has made in the years that have since elapsed. They contain 753 distinct determinations, at 670 stations widely distributed over the earth's surface; leaving, it is true, much still to be desired;—but in what has been accomplished, leading to conclusions so remarkable, in regard to the phænomena of magnetism, on the largest scale presented to us by nature, as to stimulate greatly to more extensive research.

I have sought to embody in this report on the variations of the magnetic intensity, all the materials which have been obtained by the labours of observers of all nations, in all parts of the world;—to present them in the form best fitted to add to our knowledge;—and to call attention to the general conclusions, to which we are conducted by an attentive consideration of the facts of observation, when thus brought together in one view. A large portion of these determinations are here published for the first time. The observations of Capt. de Freycinet, Capt. King, Mr. Douglas, Capt. Fitz Roy, Capt. Ross, and Major Estcourt are wholly new, the original observations having been recently communicated to me by the respective observers, and calculated and arranged by me. Messrs. Hansteen and Due's Siberian observations, and M. Erman's in the Pacific and Atlantic oceans, have been furnished to me by the liberality of those gentlemen, calculated as they appear here. Of the results previously published, the greater number are collected from different foreign works which have little circulation in this country; and some of these, as well as a part of my own observations published in this country several years ago, have required additional calculations, for the purpose of bringing them into the general comparison.

I have divided the report into three sections; the first, containing a condensed historical notice of each of the several series of observations, by which our knowledge of the magnetic intensity has been progressively advanced; the second, comprising the whole of the results, classed according to the values of the intensity, and arranged in a tabular form; and the third, containing a summary of the principal general conclusions in regard to the system of terrestrial magnetism, which are deducible from the facts thus collected.

I have endeavoured to confine the historical notices in the first section within the narrowest limits compatible with the primary object, that of including in each notice all the circum-

stances required to be known in order to estimate rightly the value of the results. In the case of observations which are either wholly or partly new, these particulars are not to be found elsewhere; and in the case of those series, the published accounts of which are contained in foreign works rarely met with in this country, it has appeared desirable,—whilst giving every direction which may facilitate a reference to the original publication,—to make the account here given complete in all particulars essential to a just estimation of the value of the results, independently of such reference. The details necessary for this purpose may render this portion of the report occasionally tedious to the general reader, who will be principally interested by that section which contains the general conclusions.

Section I.—Historical Notices.

It is to France we owe the first rightly directed experimental inquiry on this subject. The instructions, drawn up by the members of the French Academy of Sciences for the expedition of La Perouse, contain a recommendation that the time of vibration of a dipping needle should be observed at stations widely remote, as a test of the equality or difference of the magnetic intensity; suggesting also with a sagacity anticipating the result, that such observations should particularly be made at those parts of the earth where the dip was greatest and where it was least.

The experiments, whatever their results may have been, which in compliance with this recommendation were made in the expedition of La Perouse, perished in its general catastrophe; but the instructions survived, and bore fruit in the earliest recorded observations of the variations of the magnetic intensity, which are those published by M. de Rossel in the second volume of the *Voyage de Dentrecasteaux* in search of La Perouse.

Rossel, 1791–1794.—These observations, though made in the years above-mentioned, were not published until 1808. They were made with a needle vibrated in a dip circle of Le Noir, coming to rest disadvantageously soon for the purpose of experiments on the intensity. The needle continued in vibration little more than three minutes; consequently incidental errors would bear a very large proportion to the total time of vibration; a disadvantage which appears to have been in a great degree counteracted by the very great care bestowed on the observation. The needle was vibrated at Brest in 1791, before the voyage commenced; and, successively, at Teneriffe; Van Diemen's Land,

in May 1792; at Amboyna, in October of the same year; again at Van Diemen's Land, in February 1793; and at Surabaya in Java, in 1794. With this last observation the published results terminate; there is no record of the vibrations having been repeated on the return to France, for the purpose of testing the constancy of the magnetism of the needle, a step which subsequent experience has shown to be most important. The connexion of all the foreign stations with Europe is consequently imperfect; and the values of the intensity at those stations, relatively to any standard value in Europe, could only be computed, subject to the uncertainty arising from the possibility of a change in the magnetic condition of the needle. The conclusion drawn by M. de Rossel, of the increase of the intensity in receding from the equatorial to the higher latitudes, was, however, fully borne out and substantiated, in regard to the southern hemisphere, by the observations at Van Diemen's Land in 1792 and 1793, compared with the intermediate vibrations at Amboyna. These form a comparison complete in all respects, and to the certainty of which nothing is wanting. It is independent of any change the needle may have undergone before or afterwards; the correspondence of the time of vibration at Van Diemen's Land in May 1792 and February 1793, proving the needle to have been steady in that interval. The increase in the intensity between Amboyna and Van Diemen's Land was in the proportion of 1 to 1·67, a difference far too great to be attributed to any supposable errors or accidents of observation. It is this determination which unquestionably entitles Admiral de Rossel to the distinction which he has always enjoyed, of having been the first who ascertained that the magnetic intensity is different at different positions on the earth's surface: although his observations were not published until after those of M. de Humboldt in 1798–1803, by which the same fact was more largely established.

As M. de Rossel's observations have not, I believe, been published in any English work, I have subjoined a table containing an abstract of all their essential particulars.

Station.	Date.	Lat.*	Long.*	Dip.	Time of Vibration.
		° ′	° ′	° ′	″
Brest	20 Sept., 1791	48 24	355 34	71 30 N.	2·02
Teneriffe	21 Oct., 1791	28 28	343 42	62 25 N.	2·081
Van Diemen's Land	11 May, 1792	43 32 S.	146 57	70 50 S.	1·869
Amboyna	9 Oct., 1792	3 42 S.	128 08	20 37 S.	2·403
Van Diemen's Land	7 Feb., 1793	43 34 S.	146 57	72 22 S.	1·850
Surabaya	9 May, 1794	7 14 S.	112 42	25 20 S.	2·429

The times of vibration are in infinitely small arcs, being reduced by M. de Rossel, by means of a table which accompanies the observations in the original publication.

M. de Rossel's observations at Van Diemen's Land were made at a port on the S.E. part of the island. Capt. Fitz Roy has recently determined the value of the intensity at Hobart Town, about 40 miles north of M. de Rossel's station, to be 1·817, in terms of a comparative scale in general use adopted in this Report, of which an explanation will be given in the sequel. Suffice it at present to say, that in the same scale the force at Paris = 1·348, and at London 1·372. Capt. Fitz Roy's observations will be found in their place in the course of this Report. If we take his value of the intensity at Hobart Town for the force at M. de Rossel's station, we have 1·097 as the force at Amboyna. By means of Capt. Fitz Roy's observation at Van Diemen's Land, I have been thus enabled to connect M. de Rossel's determination at Amboyna with Europe, and it is accordingly entered in the general table.

Humboldt, 1798–1803.—These observations were made in the course of M. de Humboldt's well-known journey to equinoctial America. Various partial notices of them have appeared at different times and in different works, but a complete account, communicated by M. de Humboldt himself, may be found in the xvth volume of the *Annalen der Physik*, from which the results employed in this memoir are derived. The observations were made with a dipping needle of Le Noir, selected by M. Borda. It vibrated considerably longer before coming to rest than the needle employed by M. de Rossel, so as to allow the number of vibrations performed in ten minutes to be taken as the measure of the intensity at the different stations. The time of vibration at Paris was observed in October 1798, be-

* All the longitudes in this Report are east of Greenwich, unless otherwise expressed; and all the latitudes are north unless they are designated otherwise.

fore M. de Humboldt's departure; but as the needle was left in Mexico, those observations could not be made on the return to Europe, by which its magnetic invariability might have been assured. The circumstances are greatly to be regretted, whatever they may have been, which deprived a suite of observations so extensive, and on which so much care and labour had been bestowed, of a final confirmation, which can hardly be supplied in an equally satisfactory degree by any less direct evidence. Fortunately, indirect means are not altogether wanting in this case, and we may infer from them that up to the beginning of 1800 M. de Humboldt's needle had undergone no change; and that if subsequently to that date it lost magnetism, the alteration was not considerable. The observations in Paris were made in 1798. Between August 1799 and February 1800, M. de Humboldt made thirteen determinations of the intensity on the Spanish main, between the latitudes of 10° and 11°, and the longitudes of 292½ and 296½. The mean of these is an intensity of 1·196. In 1822 the value of the intensity at Trinidad, in lat. 10° 39′ and long. 298½, was determined, by observations made by myself (to be discussed hereafter), to be 1·204. The result of this comparison is extremely satisfactory; and being derived, on M. de Humboldt's side, from observations with one needle at several stations, and on mine from several needles at one station, a fair conclusion may be drawn, that in the beginning of 1800 his needle retained its magnetism unimpaired. In January, 1801, M. de Humboldt's needle gave for the intensity at Havannah 1·359; mine, in 1822, 1·499. In this comparison the agreement is less perfect; there is a greater difference than is usual between the results of different observers at the same station; and it is such as would be occasioned by a loss of magnetism in M. de Humboldt's needle, but not to an amount that would impair in a material degree the value of his important series. Against any precise inference, however, to be drawn from these comparisons, there is, 1st, the difference of the dates at which the respective intensities were determined; 2nd, a small difference in longitude of the localities of the first comparison; and 3rd, those circumstances of a local and instrumental nature which must affect every such comparison.

In the account which M. de Humboldt has given of his observations there is no mention made of corrections having been applied for the arcs of vibration or for the temperature of the needle; but in such an extensive series, corrections on these accounts are of minor importance.

The number of land-stations at which the intensity was ob-

served appears to have been 77, all of which are entered in the general table in this memoir.

Besides the land-stations, there are 12 geographical positions, in which M. de Humboldt observed the vibrations of the needle on board ship. There are two great and obvious disadvantages in such observations, compared with those on land, viz. the motion, and the iron, of the vessel. On the other side should be noticed, the space interposed between the instrument and the solid materials of the earth's surface, many of which are known to exercise a very considerable disturbing influence on the needle. As opinions may, and I believe do, vary in regard to the degree of relative value to be allowed to observations of intensity made at sea and on land, and as it is not a point on which, from personal experience, I feel qualified to decide, I have placed the sea-observations in a separate table, and subjoin them here.

Latitude.	Longitude.	Date.	Intensity.	
° ′	° ′			
38 52	345 59	1799	1·315	
37 26	345 49	1799	1·315	
34 30	345 26	1799	1·230	
31 46	345 17	1799	1·261	
24 53	341 23	1799	1·283	
3 02 S.	279 54	1803	1·067	
21 29	336 39	1799	1·261*	1·256
19 54	333 36	1799	1·251*	
14 15	314 18	1799	1·283*	1·256
13 02	309 23	1799	1·230*	
10 46	301 27	1799	1·178*	1·220
11 01	297 30	1799	1·261*	

The results marked with an asterisk were observed on the passage across the Atlantic, between Teneriffe and Trinidad, a part of the ocean where no land exists, and where, consequently, the results obtained at sea furnish the only attainable evidence. On examination, they present differences among themselves considerably greater than is usual in land results; but by combining them in pairs, as shown in the table, and using the mean latitude, longitude, and intensity of each pair, these partial differences greatly disappear. I have entered the mean latitude, longitude, and intensity of these three pairs in the general table.

Humboldt and Gay Lussac, 1805–1806.—These observations

were made during a tour in France, Switzerland, Italy, and Germany, with a needle suspended by fibres of silk, vibrating in the plane of the horizon, and measuring the horizontal component of the magnetic intensity. The dip was observed at the same time with a dipping-needle of Lenoir (the same that had been used in the *Voyage de Dentrecasteaux*), supplying the means of computing the total intensity from its horizontal component. An account of these observations was published by M. Gay Lussac in the 1st volume of the *Memoires de la Société d'Arcueil.* The values of the intensity were given in reference to the force at Paris, where the needle was vibrated at the close of the series, but not at its commencement. M. Gay Lussac infers that no change took place in the magnetism of the needle throughout the series, from its having had the same time of vibration at Milan on two occasions, viz. in going and in returning, at six months' interval. As no dates are given, the stations at which the strict comparability of the force was thereby ensured can only be conjectured. It is probable that no corrections were applied either for the arcs or for differences of temperature, as neither of these circumstances is noted in the record. The number of stations of known geographical position is 19, 16 of which are inserted in the general table in this memoir. The other stations were in the crater, on the side, and at the foot of Vesuvius, where the results were considered by the observers to be affected, as no doubt they were, by the proximity of the lava.

Sabine, 1818, 1819, 1820.—These observations were made in the first and second voyages of northern discovery to Baffin's Bay and the Polar Sea. Aware of the magnetic importance of the regions to be explored, and anxious duly to improve such opportunities, I sought diligently to provide myself with instruments adequate to the occasion. Those furnished by Government were by no means so; but it fortunately happened that my brother-in-law Mr. Browne possessed and entrusted to me a dip circle and needle of very superior character, made by Nairne and Blunt, and similar in all respects to the one made under Mr. Cavendish's directions, and described by him in the 66th vol. of the *Phil. Trans.* The needle vibrated about eight minutes before coming to rest; and probably, from its age, had long acquired the state of steady magnetism which it was proved to possess during these voyages, its time of vibration being almost identical when observed in London in March, 1818, in March, 1819, and in December, 1820*.

* The observations of March, 1819, and December, 1820, are recorded in

The observations of the voyage of 1818 were published in the *Phil. Trans.* for 1819; those of the voyage of 1819–20, partly in the appendix to the narrative of that voyage, and partly in my work entitled *Pendulum and other Experiments*, published in 1825. In these publications the results were deduced without any corrections having been made for the arc of vibration or the temperature of the needle. On this occasion I have introduced both these corrections. That for the arc has been computed by means of the table published in the *Voyage de Dentrecasteaux*, which I find to reduce the vibrations in the different arcs so nearly to an equality as fully to justify its employment. The arcs themselves are stated in the printed record of the observations. The temperatures on the different days of observation are taken from the record of the external thermometer in the Meteorological Journal, and the corrections are computed by the usual formula for that purpose, in which the coefficient ·0004 has been determined by experiments with the same needle in high and low temperatures.

In the voyage of 1819–1820 I furnished myself, besides the dipping-needle, with three horizontal needles, and an apparatus for their vibration. These would have been of great use had it been our good fortune to have returned to Europe by the way of the Pacific; but the method of deducing the total intensity by means of horizontal needles almost ceases to be available in countries where the dip so nearly approaches 90°, and where small incidental errors in the determination of the dip will so greatly affect the conclusion as to the force. Accordingly, I have at no time brought the observations with the horizontal needles in this voyage in comparison with the results given by the dipping-needle. There is, however, an incidental purpose of some value which they may serve, which did not occur to me when the record of the observations was printed, and which is worth noticing, as it may be useful on similar occasions, should there be such. The horizontal vibrations, though inappropriate in such circumstances to furnish the total intensities, give as correct measures of the relative values of the horizontal component

the Appendix of the second Polar Expedition. From the circumstance of the narrative and appendix of that voyage having been published at an interval of some months apart, the copy of the narrative which reached M. Hansteen was unaccompanied by the appendix, which it seems he has never seen. The abstract of the results, published in another work from whence he has taken them, refers to the full record of the observations in the appendix, and omits their dates, and Mr. Hansteen has consequently been at a loss to know whether the vibrations were observed both before and after the voyage of 1819—1820. By consulting the original account, he will see that this necessary care was not omitted.

of the force at any two stations, as the vibrations of the dipping-needle do of the total force. If, then, T is the time of horizontal vibration, and D the dip at a primary station, where the total force is taken as unity,—and if T' and D' are the same quantities at another station, where I' is the value of the total intensity derived by the vibrations of the dipping-needle,—$\cos D' = \frac{T^2 \cdot \cos D}{I' \, T'^2}$; and we thus get a determination of the dip distinct from the ordinary method, and independent of the instrumental errors from which it is so difficult to clear the dipping-needle, especially one in which the poles are not reversed in every observation.

Employing the observations at Melville Island, printed in the appendix to the account of that voyage, in this manner, we obtain the dip at Melville Island by the three horizontal needles as follows, viz.

Needle 1	88° 44′
Needle 2	88 46
Needle 3	88 48

The direct observation by the dipping-needle was 88° 43′·5.

The following table exhibits the results of the observations of intensity in the two north polar voyages above noticed, corrected for temperature and arc, and expressed in terms of the general scale.

Station.	Latitude. ° ′	Long. ° ′	Therm.	Time of Vibration. Observed.	Time of Vibration. Correct.	Intensity.
London, 1818	51 31	359 52	48	480	472·0	1·372
London, 1819				482	473·5	
London, 1820				480	472·9	
Shetland, 1818	60 09	358 48	44	470	461·7	1·434
On Ice	68 22	306 10	34	440	432·1	1·643
Hare Island	70 26	305 08	34	443	434·9	1·622
On Ice	75 05	299 37	33	447·2	439·4	1·590
On Ice	75 51	296 54	33	443·6	435·6	1·618
On Ice	76 45	284 00	33	435·0	429·1	1·666
On Ice	76 08	281 39	33	436·0	430·0	1·659
On Ice	70 35	293 05	33	436·0	429·7	1·661
On Ice, 1819	64 00	298 10	32	437·4	435·0	1·621
Possession Bay	73 31	282 38	40	439·5	432·9	1·637
Regent's Inlet	72 45	270 19	32	439·0	428·9	1·668
Byam Martin's Island	75 10	256 16	32	442·5	430·7	1·653
Melville Island	74 27	248 18	20	444·3	434·6	1·624
Winter Harbour	74 47	249 12	43	446·2	432·6	1·638

Hansteen, 1819–1825.—In 1819 M. Hansteen, having com-

pleted and published his elaborate exposition of the theory of the earth's magnetism, to which he had been conducted by the study of the phænomena of the variation and dip as far as they were then known, entered into the field of experimental research, in which he has since rendered such important practical services to his favourite science. His exceedingly portable apparatus for determining the intensity by horizontal needles is too well known to need description here; and his good fortune in possessing a needle of remarkably steady magnetism, supplied by Mr. Dollond, renders little more necessary to be said in regard to his determinations, than to refer to the publications in which they may be found, and to enter them in the general table. From 1819 to 1824 his observations were confined to Norway and the shores of the Baltic, and were published in the iiird vol. of the *Ann. der Physik*, the intensity stations being 37. In 1825 he extended them round the shores of the Gulf of Bothnia; and the determinations of that year, being 30 in number, were published, first, in the ixth vol. of the *Ann. der Physik*, and, secondly, with corrections, in the *Astro. Nach.*, No. 146.

Erichsen, 1824; *Keilhau and Boeck*, 1825–1827; *Erman*, 1826.—I have classed these observations together, because they were all made, I believe, at the instance and with the apparatus of M. Hansteen, and were communicated to the public through him in the *Astro. Nach.*, No. 146. Captain Erichsen's consist of 3 stations on the shores of the Baltic, and in Germany; Messrs. Keilhau and Boeck's of 9 stations in Germany; and M. Erman's of 2 stations in Germany. They were all connected with Paris through Christiania, and are entered in the general table.

Sabine, 1822–1823.—These observations were made during two voyages, in which I was furnished by the British Government with a vessel for my conveyance to stations at remote latitudes from each other, for the purpose of determining the amount of the ellipticity of the earth by means of the pendulum. The first voyage was to the equatorial shores of the African and American continents, and the second to the north of Europe, Greenland, and Spitzbergen. For these voyages I supplied myself with as many as six horizontal needles, in anticipation that some amongst them might prove unsteady in their magnetism. The observations with all the needles, and at all the stations visited, were published in 1825, with the account of the pendulum experiments.

One of the needles, No. 2, lost so much of its magnetism in

the first voyage that it was not used in the second. Another, No. 1, appears to have been subject to fluctuations in its magnetic condition, rather than to have undergone permanent or uniform gain or loss. M. Hansteen, who has discussed these observations at some length in the ixth volume of the *Annalen der Physik*, has rejected the results with these two needles whenever they differed considerably from those of the other four; but has retained and allowed weight in the general mean to such of their results as appeared to agree with the other needles. Nos. 3, 4, 5, and 6 showed on their return to England small and comparatively unimportant differences from their times of vibration previous to their departure. M. Hansteen has applied corrections on this account to the intervening observations, according to their dates. One of my stations having been Drontheim in Norway, which was visited by M. Hansteen himself for the same purpose in 1825, two years after I had been there, it became a station common to our respective series; and he was thereby enabled to compute the values of the intensity at all the stations visited by me, relatively to the force at Drontheim, which he had already compared with Paris by observations at Drontheim and Christiania, and at Christiania and Paris. The values so computed and published by M. Hansteen in the volume of the *Ann. der Physik* referred to, are here subjoined, for the purpose of exhibiting them in comparison with my own deductions. The latter are made from the observations with Nos. 3, 4, 5, and 6 alone, those of Nos. 1 and 2 being put wholly aside. The times of vibration of each needle at the different stations, as originally published in 1825, have received three corrections: one, when necessary, for change of magnetism, assigned on the principle of uniform gain or loss; a second, to diminish the observed times of vibration to the corresponding times in infinitely small arcs; and a third for reduction to a standard temperature of the needle, the coefficients for the formula having been determined experimentally for each needle. The values of the intensity in my deductions are given relatively to the force in Paris, by my own comparison of the force in London and in Paris, which will be noticed hereafter. There are, therefore, several particulars in which M. Hansteen's mode of deduction and mine differ; but it is interesting to perceive how nearly the results agree. The values calculated by M. Hansteen are almost everywhere slightly in defect of those computed by me. This arises from the force at Drontheim being somewhat less by M. Hansteen's observations than by mine; and as he has compared the intensity at all my stations with that

at Paris through the observations at Drontheim, the original difference between us at Drontheim pervades the whole series.

Place.	Hansteen.	Sabine.	Place.	Hansteen.	Sabine.
Bahia	0·894	0·898	Madeira	1·382	1·373
Ascension	0·900	0·920	Jamaica	1·414	1·436
St. Thomas	0·921	0·931	Drontheim	1·430	1·442
Maranham	1·006	1·016	Grand Cayman .	1·430	1·454
Sierra Leone ...	1·043	1·053	Havanna	1·493	1·499
Gambia River...	1·129	1·141	Hammerfest ...	1·493	1·506
Port Praya	1·184	1·193	Greenland	1·512	1·530
Trinidad	1·183	1·204	Spitzbergen	1·531	1·562
Teneriffe	1·300	1·313	New York	1·794	1·803

In the deductions contained in this table (both in M. Hansteen's and mine) the dips employed are those which M. Hansteen has calculated from my published observations. They differ occasionally a minute or two from my calculated results, but in no instance does the difference amount to 3′.

Lütke, 1826–1829.—These observations were made by Captain (since Admiral) Lütke, of the Russian Imperial Navy, in a voyage of circumnavigation in H.I.M. ship Siniavin. At the request of Capt. Lütke, M. Lenz, of the Imperial Academy of Sciences at St. Petersburg, undertook to arrange them for publication, and they have since been published in the German language in the Memoirs of the Imp. Acad. of Sciences for 1835. I was indebted to the friendship of Capt. Lütke for an early knowledge of these observations, having received a copy of them in a letter from Norfolk Sound in July 1827; but the present notice, as well as the results entered in the table, are taken from the published account.

M. Lenz's memoir is divided into two sections,—on the observations of Dip,—and on those of Intensity. Our present purpose is with the latter section.

The observations of intensity were made with one dipping and five horizontal needles. The dipping-needle was 3½ inches in length, with a steel axle, and was reserved exclusively for measuring the intensity by its vibrations, as there were two other dipping-needles for observations of the dip. The horizontal needles were of various shapes, cylindrical, rhomboidal, and elliptical, but all of the same length, i. e. two English inches. They were obtained in England when the Siniavin was on her outward passage. The apparatus in which they were to have

been used was unfortunately broken in pieces in the carriage from London to Portsmouth by mail. It had been Capt. Lütke's intention to have vibrated the needles at Portsmouth before his departure, and again at the same spot on his return from the Pacific; so that all the observations of his voyage with each needle might have been comparable with its rate at Portsmouth. The accident which prevented the execution of this purpose, and rendered the series of observations much less complete than it would otherwise have been, is much complained of both by Capt. Lütke and M. Lenz. In consequence of this accident, it was not until the arrival of the Siniavin at Kamtschatka that the needles could be vibrated at a station to which they were subsequently brought back; and out of 52 stations, there are only 18 which were observed at during an interval in which anything is known by observation of the steadiness of the magnetism of the needles. They were vibrated at three different dates at the harbour of St. Peter and St. Paul, viz. on September 30, 1827, June 6, 1828, and October 9, 1828. Their changes of rate in the intervals were small, but not proportionate. Corrections are computed and applied at all the intermediate stations in the usual manner. M. Lenz has employed the rate of change of each needle, deduced from the first and second times of vibration at St. Peter and St. Paul, to furnish corrections for the stations observed at antecedently to Capt. Lütke's first arrival at Kamtschatka; of these the land stations are Rio de Janeiro, Concepcion, Valparaiso, Sitka and Unalaska. For a single station (Manilla) observed at subsequently to the final departure from Kamtschatka, M. Lenz has used the rate of correction deduced from the second and third times of vibration there.

The times of vibration were derived on all occasions from the mean of 250 consecutive vibrations, commencing with an arc of 30° and ending usually about 10°. M. Lenz has not considered it necessary to apply a correction for the arcs. The value of the correction to a mean temperature was determined for each needle by observations made at St. Petersburg at the conclusion of the voyage. For four of the five needles the correction was as usual additive to the time for temperatures below the standard, and subtractive for those above it; but one needle, rhomboidal in shape, exhibited the anomaly of a decrease of force in the colder temperatures, fully as great as the increase shown by any of the others. The observations appear to have been very carefully made,—were repeated four times,—and include a difference of temperature of 20° Reaumur. A similar anomaly has been noticed, if I remember rightly, by M.

Kupffer, as having occurred in his experience, and I have myself met with an instance of the same kind. M. Lenz has employed no correction for this needle; and the vibrations of the vertical needle appear also to have been uncorrected for temperature.

The harbour of St. Peter and St. Paul is the fundamental station of Capt. Lütke's determinations. The value of the intensity there, 1·447 to 1·348 at Paris, is stated by M. Lenz to be taken on the authority of M. Hansteen.

Capt. Lütke used both his dip and intensity needles at sea in favourable weather, placing the instruments on a board suspended in gimbals above the companion. His sea observations appear to be viewed by M. Lenz as not entitled to equal weight with those at the land stations, but as valuable additions. Of 51 intensity results, 16 are at land stations, and are entered in the general table; and I subjoin, as in the case of M. de Humboldt's, a separate table of the 35 results obtained at sea.

Lat.	Long.	Date.	Intensity.	Lat.	Long.	Date.	Intensity.
SOUTH.		1827.		NORTH.		1827.	
29° 10′	313° 35′	16 Jan.	(a) 0·924*	0° 35′	232° 56′	8 May	(b) 1.013
40 55	307 0	25 Jan.	(a) 1·110	2 24	232 08	9 May	(b) 1·012*
49 18	302 48	31 Jan.	(a) 1·268	13 13	227 0	19 May	(b) 1·112*
53 16	301 37	3 Feb.	(b) 1·320*	23 26	218 02	25 May	(b) 1·212*
55 25	298 27	8 Feb.	(b) 1·413	25 21	213 56	30 May	(b) 1·376*
41 00	282 30	1 March	(b) 1·324	40 28	213 35	1 June	(b) 1·456
29 38	278 26	11 April	(c) 1·153*	44 54	214 50	3 June	(b) 1·573*
21 51	268 05	18 April	(c) 1·046*	48 44	216 37	6 June	(b) 1·653
13 09	251 20	27 April	(c) 1·014	52 29	219 08	9 June	(b) 1·662*
9 38	243 25	30 April	(c) 1·141*	45 27	159 02	23 Oct.	(b) 1·303
6 01	240 08	2 May	(b) 1·005*	39 07	159 03	26 Oct.	(b) 1·186
4 20	238 13	3 May	(b) 0·998	32 59	161 49	1 Nov.	(b) 1·113*
2 29	236 26	4 May	(a) 1·000*	18 44	163 55	13 Nov.	(b) 0·989
2 02	236 04	4 May	(b) 0·996*	11 27	161 52	18 Nov.	(b) 0·970
1 15	225 30	5 May	(c) 0·989*	4 17	162 54	23 Dec.	(a) 1·001
1 10	234 31	6 May	(b) 0·995*	3 47	162 59	23 Dec.	(a) 1·010
0 56	233 17	7 May	(c) 0·990*	2 56	162 50	24 Dec.	(a) 1·018
						1828.	
				6 55	158 02	7 Jan.	(a) 0 990

The results with an asterisk are so marked in M. Lenz's memoir to signify observations made under less favourable circumstances than the others. The sixteen which are not so marked are entered in the general table.

(a) designates results obtained by means of the horizontal needles; (b) those by means of the dipping-needle; and (c) results which are a mean of both methods.

King, 1826–1830.—These observations were made during

a survey of the coast of South America from Rio de Janeiro to Valparaiso, carried on under the orders of the British Government by Capt. Philip Parker King of the Royal Navy. They were undertaken at the request of M. Hansteen, and with an apparatus for horizontal vibration with which Capt. King was furnished by him. A copy of the observations was transmitted from time to time, as they were made, to M. Hansteen, who employed the results, computed provisionally, in his map of the intensity, published in the *Annalen der Physik*, vol. xxviii. The observations themselves have not yet been published, having been given by Capt. King to his successor in the survey, Capt. Fitz Roy, to be published when the latter should return to England. On his return, which took place late in 1836, Capt. Fitz Roy placed Capt. King's magnetic observations in my hands (together with his own, of which a separate notice will be given in the sequel,) to calculate and arrange for publication in an account which he is now preparing for the press, of the proceedings of Capt. King and himself during the survey. Meantime I have Capt. Fitz Roy's permission to introduce Capt. King's results into this memoir.

The needle with which M. Hansteen supplied Capt. King sustained a very considerable loss of magnetism during the four years it was employed by that officer. Its time of vibration increased between March 22, 1826, and January 24, 1831, (on which days it was tried in the garden of the Royal Observatory at Greenwich,) from 734·5 seconds in 1826, to 775·8 seconds in 1831. A change of such magnitude in the magnetic intensity of the instrument employed to measure the variations of the terrestrial intensity, and which ought itself, therefore, to be invariable, would, in ordinary circumstances, have prevented any satisfactory conclusion whatsoever being drawn from the observations. Fortunately, from the nature of the duties in which Capt. King was engaged, he had occasion to return frequently to the same anchorages; and as he was extremely careful to re-examine the needle on every such return, we have the means of knowing by direct observation the amount of the loss it sustained in certain portions of the time of its employment. There are eleven stations at which the force was observed on the east and west coasts of South America, and two in ports of the Atlantic on the outward voyage. By the practice referred to, of repeating observations at the same station at distant intervals, the South American stations are so linked together and connected, that by adopting a method similar to that used in determining chronometrical differences of longitude, we may compute and assign the intensity at each, in reference to

one selected, and regarded in the same light as a first meridian. In justice to these valuable observations, and in consideration of the great change undergone by the needle, it may be desirable briefly to describe the manner in which this has been done.

At Rio de Janeiro, which was the first station observed at in South America, the needle was vibrated in August 1826, September 1827, and December 1828; in the intervals between these dates are comprised the principal part of the observations on the east side of South America. There is no direct observation at Rio subsequently to December 1828, but we are able to supply the time of vibration at a fourth date in the following manner. The intensity at Rio and at Monte Video having been correctly compared by a double comparison in 1827 and 1828, the needle was vibrated at Monte Video on the 1st of June, 1830, immediately before Capt. King's departure for England, and we thus obtain by an easy calculation the time of vibration at Rio corresponding to the same date. The intervals between these four dates include the whole of the South American stations; and we have only to distribute in each interval the loss of magnetism which the observations show to have taken place from one date to the next, in the manner which may appear most suitable. There is no very obvious indication that the loss was other than gradual; and by considering it uniform in each separate interval, the results are found extremely accordant at several other stations at which observations were repeated at distant intervals. The subjoined tables will enable the reader to judge of this for himself. In the first table are shown the times of vibration at Rio, corresponding to the four dates: 1st, the observed times of horizontal vibration reduced to infinitely small arcs and to a temperature of 60°; and 2nd, the corresponding times as a dipping-needle. The value of the correction for temperature has been determined for this needle by observations which I have recently made with it for that purpose, the particulars of which will be given in the more detailed statement in Capt. Fitz Roy's publication. In the three last columns are shown,—the number of days comprised in each interval,—the increase in the time of vibration owing to loss of magnetism in the needle,—and the resulting daily correction on the supposition of the loss in each interval being uniform.

The second table contains the corrected times of horizontal vibration at each of the South American stations at the dates respectively inserted;—the dips observed by Capt. King;—the time of vibration as a dipping-needle *at Rio* at the same dates,

derived from the observations in the first table;—and the resulting intensity at the station relatively to Rio. The contents of the tables thus far are the results of Capt. King's observations, unmixed with those of any other observer. We have now to express his results in terms of the general scale of comparison, and this is done in the final column, by taking the value of the intensity at Rio at 0·884, which is the mean of four independent determinations by the following observers, viz.:

1817 and 1820	Freycinet . . .	0·890	0·884
1827	Lütke	0·886	
1830	Erman	0·879	
1836	Fitz Roy . . .	0·878	

I have included in table II. Madeira and Port Praya, at which Capt. King observed in his outward passage. The dates of these fall between the observations at Greenwich in March, 1826, (corrected time = 734·0 and dip 69° 52′,) and those at Rio in August, 1826. Having the intensity at Greenwich = 1·372 and at Rio = 0·884, we have the time of vibration as a dipping-needle at Rio at the respective dates as follows:

March, 1826	536·2
August, 1826	537·0

It appears, therefore, that only a very slight change took place in the magnetism of the needle during the outward voyage, and we may take 536·6 as the time of vibration at Rio, corresponding to the dates of the observations at Madeira and Port Praya. I have assumed the dip and force at Greenwich to be the same as at London. The dip at Madeira was not observed by Capt. King, but has been supplied from my own observations in 1822, which were made in the same locality, namely, the Consul's garden in Funchal, where Capt. King's needle was vibrated. I have deducted 12′ from my determination of the dip at Madeira for the probable change between 1822 and 1826.

TABLE I.

Rio de Janeiro, Dip 14° 00′.	Time of Vibration.		Interval.	Loss.	Per diem.
	Horizontal.	As a dipping-needle.			
	s.	s.	Days.	s.	
August 29, 1826...	545·2	537·0			
			382	6·5	·017
September 15, 1827	551·8	543·5			
			462	9·2	·020
December 21, 1828	561·1	552·7			
			527	2·7	·005
June 1, 1830	563·8	555·4			

Table II.

Station.	Date.	Time of horizontal vibration.	Observed dip.	Time as a dipping needle at Rio.	Intensity, Rio =1·000.	Intensity, Rio. =0·884.
		s.	° ′	s.		
Madeira............	1826, May 31............	627·79	62 0·0 N.	536·6	1·556	1·377
Port Praya	1826, June 22 & 24......	557·08	45 44·7 N.	536·6	1·330	1·177
St. Catherine......	1827, Nov. 3	553·58	22 12·4 S.	544·5	1·045	0·920
Gorriti	1826, Oct. 29 & Nov. 6	549·44	35 05·9 S.	538·1	1·172	1·041
——	1829, Jan. 10	562·78	....	552·8	1·179	
Monte Video......	1827, Dec. 18............	553·87	36 28·4 S.	545·4	1·206	
——	1828, Oct. 8	560·95	....	551·3	1·201	1·065
——	1830, June 1	564·89	....	555·4	1·202	
Sea-bear Bay ...	1829, March 20	576·37	53 13·5 S.	553·1	1·538	1·361
St. Martin's Cove	1827, Jan. 15 & 22......	584·29	59 43·8 S.	539·4	1·691	1·498
——	1827, March 27	585·08	....	540·6	1·694	
Port Famine......	1828, Jan. 28	589·36	59 52·6 S.	546·2	1·712	
——	1828, May 8	596·54	....	548·2	1·683	1·505
——	1828, June 18 & July 20	595·81	....	549·3	1·694	
——	1830, April 26	598·97	....	555·1	1·712	
Chiloe	1829, Sept. 1 & Dec. 15	565·23	49 52·6 S.	554·2	1·402	1·321
Juan Fernandez .	1830, Feb. 19	551·83	44 49·8 S.	554·8	1·425	1·262
Talcuhuano	1829, Dec. 28............	555·59	45 10·0 S.	554·6	1·413	1·250
——	1830, May 12............	557·18	....	555·3	1·412	
Valparaiso.........	1829, Aug. 4	548·59	40 10·7 S.	553·9	1·334	1·176
——	1830, Jan. 11 & Feb. 1 .	551·6	....	554·6	1·324	

Sabine, 1827.—These observations were made for the purpose of determining the ratio of the intensity in Paris and London, in order to connect and unite in one system, the results of the different observers who had made Paris and London respectively the base stations of their series.

All values of the intensity hitherto determined are *relative* values; that is to say, each observer has taken some one station as the fundamental one of his series, and has expressed the values of the intensity at all his other stations, comparatively with the force at his fundamental station. Unless, therefore, two such series have one station common to both, or unless the force at their respective fundamental stations has been otherwise compared, they do not form parts of one system, and the results of the one series cannot be brought into connexion with those of the other.

The continental observers in general have taken Paris, either mediately or immediately, as their fundamental station; and the English observers have as generally taken London; the present observations were designed, therefore, as a link to connect their respective series into one system.

Six horizontal needles were employed for this purpose, and a number of observations were made with them at different dates at both places; the details are published in the *Phil. Trans.* for 1827. From these it appears that, if the horizontal intensity in London be designated as unity, the several needles gave its value in Paris as follows, viz.:

Needle IV. = 1·0732		Needle XI. = 1·0723
„ VIII. = 1·0675		„ A. = 1·0709
„ X. = 1·0726		„ B. = 1·0717
	Mean 1·0714.	

The observations were corrected for a small excess of temperature in the experiments at Paris over those in London, being, I believe, the first time in which a correction for difference of temperature was introduced into any published results of the variations of intensity at different stations. The places of observation were the magnetic cabinet of M. Arago at Paris, and the garden of the Horticultural Society at Chiswick, near London.

In order to deduce the relative values of the total intensity from their observed horizontal components, we require the dip at the two stations as accurately as it can be inferred from nearly cotemporaneous observations. In August, 1828, the dip in the garden at Chiswick was observed by Mr. Douglas and myself, 69° 46·9. *Phil. Trans.*, 1829. In a paper of M. Hansteen's, in the *Annalen der Physik*, vol. xxi. p. 414, we find recorded the following observations at Paris, a part of which fall on either side of the London observation of August, 1828, viz.:

		°	′
1825	Arago	68	00
1826	Humboldt and Mathieu . .	67	56·5
1827	Humboldt and Mathieu . .	67	58·0
1830	Arago	67	41·3

The months in which the observations were made are not named by M. Hansteen, but M. de Humboldt in a paper in the xvth vol. of the *Ann. der Physik* mentions that those of 1825 and 1826 were made in August and September, and I have taken those of 1827 and 1828 as corresponding to the same months. Allowing then an annual decrease of dip of 2′·8 (*Ann. der Physik*, vol. xxi. p. 419) we obtain the dip in Paris in August, 1828, as follows:

		°	′	
1825	Arago	67	51·6	67° 51′·15
1826	Humboldt and Mathieu	67	50·9	
1827	Humboldt and Mathieu	67	55·2	
1830	Arago	67	46·9	

I have therefore taken 67° 51′·2 as the most satisfactory co-

temporaneous result that I can obtain for Paris, all the observations being made in M. Arago's magnetic cabinet. It appears therefore, that about the period in question, the dip in London exceeded that in Paris by 115′·7; preserving this difference in the dips at the two stations when reduced to the period of the horizontal observations in 1827, and combining them with the observed horizontal intensities, we obtain 1·018 as the value of the total force in London to unity in Paris.

Such being the case, if any other number than unity be taken for the measure of the force in Paris, the corresponding value in London will be the product of that number multiplied by 1·018. By the observations of M. de Humboldt already described, the intensity at Paris to that of a place in Peru, where the needle had no dip, was found to be as 1·3482 to 1·000. As at that period it was supposed that an equal intensity, being the minimum on the surface of the globe, prevailed at all places where the needle had no dip, the station at which M. de Humboldt had observed in Peru appeared the proper unity of the system of intensities. Subsequent experience, however, has shown that the intensity lines follow a very different course from the dip lines; and in retaining the expression of unity for the force observed by M. de Humboldt in Peru, we are necessitated to employ terms less than unity to express the force in many other of the inter-tropical parts of the globe, and even in one quarter beyond the tropic. The scale is therefore purely arbitrary; but it is in general use, and will probably continue to be employed till experiments (perhaps those of M. Gauss) shall have determined an absolute value for the magnetic intensity at some one station; when all the relative intensities may be converted into the corresponding absolute intensities. Such is the origin of the number 1·3482 employed by observers generally as expressing the force at Paris. In assuming a constant expression for the force at any station on the globe for any considerable number of years, we are of course subject to error resulting from the secular change in the intensity; of the amount of which we have as yet no definite knowledge.

The force in London relatively to the above value of the force at Paris is $1{\cdot}3482 \times 1{\cdot}018 = 1{\cdot}372$.

In the spring of 1828 two of the needles used in this comparison were interchanged between M. Hansteen and myself, for the purpose of determining in a similar manner the ratio of the horizontal intensity at London and Christiania. The observations are detailed in the Journal of the Royal Institu-

tion for 1830, p. 29. They gave the following results for the horizontal intensity at Christiania to unity in London:

Needle IV.	Comparison in March . .	0·9124
	Comparison in May . . .	0·9157
„ VIII.	Comparison in March . .	0·9157
	Comparison in May . . .	0·9160
	Mean . . .	0·9147

We have seen that the observations in Paris and London gave 1·0714 for the horizontal intensity at Paris, also to unity in London; consequently Christiania to Paris is as 0·9147 to 1·0714, or as 0·8537 to 1. In the spring of 1828 M. Hansteen observed the dip at Christiania 72° 16′·2; at Paris at the same time, or about four months before August 1828, we may consider it to have been 67° 52′·5. The total intensity at Christiania derived from this comparison is therefore 1·423. The result of a direct comparison between Paris and Christiania made by M. Hansteen in 1825 is 1·419.

All the values of the intensity inserted in this memoir were originally observed in reference to one of these three stations, Paris, Christiania, or London, mediately or immediately. They have been united by means of the comparisons above noticed, viz., those of Paris and London, and of Paris and Christiania; and they now form one connected series.

Keilhau, 1827.—These observations were made in a voyage to Finmarken and Spitzbergen, in which M. Keilhau was furnished with an horizontal apparatus of M. Hansteen's, and a 5-inch dip circle and two needles made by Dollond. The observations were communicated to M. Hansteen, and the results were published by him in the xivth vol. of the *Annalen der Physik*, from whence I have taken them.

There may be remarked in these results greater differences of intensity between stations near to each other than are usually met with. From the geological character of the countries, it is probable that a portion of these may be due to local circumstances; but it is also probable that a considerable portion of them may be attributed to the inadequacy of the dipping-needle with which M. Keilhau was furnished, to give results sufficiently exact for the computation of intensities, in a part of the globe where a small error in the dip will occasion a very considerable one in the deduced intensity. His two dipping-needles frequently gave results at the same station differing from twenty to thirty minutes from each other.

There are 20 stations determined by M. Keilhau in Norway,

Finmarken, and Spitzbergen, all which are inserted in the general table.

Hansteen and Due, Erman, 1828–1830.—In 1819 M. Hansteen published his celebrated work on the magnetism of the earth, in which he brought into one view a larger body of observations of the *dip* and *variation* than had been brought together by any previous philosopher; and by subjecting them to a close examination, drew this remarkable inference in regard to the *intensity*; namely, that a centre, or pole as it might be termed, of magnetic intensity must exist in the north of Siberia, less powerful, but otherwise similar to the one in the north of America; and that the lines of equal intensity would be found to arrange themselves around the Siberian centre in the same way as around the centre of greater force in America. At the time M. Hansteen drew this inference not a single observation of the intensity had been made nearer to Siberia than Berlin on the one side and Mexico on the other.

M. Hansteen's work, much more read on the Continent than in England, produced a very general desire that an inference so remarkable, and so important if confirmed, should be submitted to the test of experiment. This, however, exceeded individual means to accomplish; it was one of those undertakings in science for which national aid is required. To the honour of Norway, the funds for this undertaking were furnished by a unanimous vote of the Norwegian Storthing or Parliament. In 1828 M. Hansteen, accompanied by Lieut. Due, proceeded at his country's expense, and with every facility which could be afforded him by the Russian Government, on a journey expressly for magnetic observations through the Russian dominions in the north of Europe and Asia. They were provided with a dip circle and two needles of Gambey's, and with M. Hansteen's apparatus for horizontal vibrations. At St. Petersburg they were joined by M. Erman of Berlin, proceeding on a similar mission to the same countries, and similarly furnished with magnetic instruments. The three gentlemen travelled together to Siberia, MM. Hansteen and Due on the one part, and M. Erman on the other, making the same observations everywhere, but independently of each other. They wintered at Irkutsk; and the following year MM. Hansteen and Due returned to St. Petersburg by land route, and M. Erman proceeded by Ochozk to Kamtschatka, where he embarked for Europe. The maps attached to this memoir mark by the observations entered on them their various journeys, separately and together, in northern Asia. Suffice it

here to say, that, they traversed the whole of the north of Europe and of Asia longitudinally, and descended the rivers Oby and Jenesei to the polar circle, with a view of determining the latitude and longitude of the Siberian pole or centre of magnetic intensity; and that its general phænomena were found to correspond in a very remarkable degree with M. Hansteen's anticipations, its locality being removed but a few degrees (about 6°) to the eastward of the position he had previously assigned to it.

Soon after M. Hansteen's return, he published a general map of the magnetic intensity, in the xxviiith vol. of the *Annalen der Physik.* I am not aware that he has as yet published any detailed statement of the results of his journey. The stations inserted in the table in this memoir are from a MS. copy of his and Lieut. Due's observations, which, with the liberality that has hitherto characterised the labours of those engaged in this interesting inquiry, and which I trust may long continue to do so, he sent me from Irkutsk in 1829, with permission to make "every use of it that I might think proper, especially when it can encourage to new undertakings, and accordingly forward the science."

M. Hansteen's determinations of intensity have a very great advantage in the perfect invariability of the needle he employed. For sixteen years in which it was in constant use no sensible alteration took place in its magnetism. This is an advantage which only those can duly appreciate who have been much engaged in making or in computing observations of this nature. The correction for temperature also, which he determined experimentally in the usual manner, has received the fullest practical confirmation, by the exact agreement, when corrected by it, of observations at the same place in temperatures differing nearly 90° of Fahrenheit.

M. Erman's intensity observations are not yet published; they are to form a part of the second volume of the scientific portion of his journey, the first volume of which was published at Berlin in 1835. He has, however, communicated their results, provisionally computed, with corrections applied for temperature and arc, in the xviith vol. of the *Annalen der Physik,* from whence I have extracted them.

The number of stations entered in the table are, 80 observed by MM. Hansteen and Due, and 98 by M. Erman. These are all in the north of Europe and Asia, and 46 are common to M. Erman and MM. Hansteen and Due. There are besides four land determinations of M. Erman's on his homeward voyage, viz., Sitka, St. Francisco in California, Otaheite, and Rio

de Janeiro. He made also a very extensive series of intensity observations on board ship in his passage from Kamtschatka to Europe. Of these he has not yet communicated the numerical results. He observed the vibrations of a dipping-needle placed on an apparatus contrived to guard against the ship's motion, which is understood to have been very successful*.

Kupffer, 1829.—These observations were made in a scientific journey to the Caucasus, undertaken by the order of the Emperor of Russia. M. Kupffer was furnished with two horizontal needles, one of which he received from M. Hansteen, and the other from myself through M. de Humboldt. He employed them, between May and August, 1829, at St. Petersburg, Moscow, Stavropol, two stations in the Caucasus, Taganrog, and Nicolaieff; and on his return to St. Petersburg, presented to the Imperial Academy of Sciences a report on the general results of his journey, in which the times of vibration of the needles are specified, together with the temperatures and the observed dips; but the conclusions, in regard to the relative intensity at the different stations, were deferred, until the corrections for temperature for the two needles could be experimentally investigated. I am indebted to M. Kupffer for a printed copy of this report, and I have

* Since this report passed from my hands into those of the Assistant-general Secretary, I have been favoured by M. Erman with a complete copy of his observations, including those made at sea. On hearing from M. de Humboldt that I was engaged in drawing up this report, M. Erman, with great liberality and most obligingly, sent me a copy in manuscript of the whole of his results provisionally computed. I have thus been enabled to add five or six stations between Ochozk and the harbour of St. Peter and St. Paul with which I was previously unacquainted, and 167 observations made on his voyage from Kamtschatka to Europe. I consider these last observations particularly valuable, in the evidence they afford, that determinations of the intensity can be made at sea with an accuracy but little inferior to those on land. With the exception of a few in the very early part of the voyage, which appear from some cause to give somewhat lower intensities than accord with M. Erman's own observations at Sitka and St. Francisco, the results, both in the Pacific and Atlantic, whenever they approach the land stations of other observers, present a most satisfactory accordance.

The complete series of M. Erman's magnetic determinations is the most extensive contribution yet made to the experimental department of magnetical science; nor can we rate its value too highly, since it furnishes us with consecutive determinations of dip, variation, and intensity, by the same highly qualified observer, and with the same excellent instruments, extending through all the meridians of the globe, and from the Arctic circle in Siberia to nearly 60° of south latitude, the whole of this distance being traversed in the course of two years, and the track completely marked by the frequency of the observations.

seen no later publication containing his own conclusions from his observations. The results entered in the table are consequently computed by myself from the report above noticed, and are uncorrected for temperature, which is of the less importance as the differences of temperature were not considerable. It is not stated in the report that the needles were re-examined at St. Petersburg at the close of the series; but as the two give results very nearly accordant, it is probable they underwent little or no loss. At one of the stations in the Caucasus no dip was observed; consequently no total intensity can be computed. Some error has obviously taken place in regard to the observations at Moscow; the times of vibration of both needles as given in the report would correspond with a very much higher intensity there than at St. Petersburg, which we know from the concordant observations of MM. Erman and Hansteen is contrary to fact. M. Hansteen, who received the observations direct from M. Kupffer at St. Petersburg, has omitted the Moscow results in his notice of this series. I have therefore done the same, supposing that there is some satisfactory reason for the omission with which I am unacquainted. At Stavropol and Taganrog the dips employed in the reduction were observed with an inferior instrument, the principal dipping-needle having met with an accident.

Quetelet, 1829–1830.—In 1829 M. Quetelet, Director of the Royal Observatory at Brussels, made observations on the horizontal intensity at several stations in Germany and the Netherlands, with an apparatus similar to M. Hansteen's and two needles; and in the following year in France, Switzerland, and Italy with the same apparatus and four needles. The observations of 1829 are contained in a memoir printed in the 6th vol. of the *Memoires de l'Academie Royale de Bruxelles*; those of 1830 in the *Annalen der Physik*, vol. xxi. Unfortunately, the greater part of the observations of horizontal intensity are unaccompanied by observed dips, and the stations are comparatively few at which M. Quetelet either observed the dip himself or has selected dips observed by others, so as to be available for our present purpose. There are ten such stations entered in the general table. Having vibrated his needles in Paris in 1830, the values of the intensity are deduced by direct comparison. He has corrected the observations for temperature, employing for their reduction the coefficient determined by M. Hansteen for his own needle.

Douglas, 1829–1834.—These observations were made by Mr. David Douglas during a journey to the N.W. coast of America, undertaken for botanical and geographical objects. The circumstances of his much-regretted death at Owhyhee in the spring of 1834, whilst waiting for a vessel to convey him home to England, are too well known to need repetition here. Having been supplied with instruments for a part of the scientific purposes of his journey by the Secretary of State for the Colonies, his papers on such subjects were sent by the British Consul at the Sandwich Islands to the Colonial Office, and on their arrival in England were placed in my hands to examine and report upon. The books containing the magnetical observations showed, by the completeness of the record, the attention and care bestowed on every circumstance which could conduce to accuracy. A full report on these, and on his other scientific papers, has been presented to Lord Glenelg, the present Secretary of State for the Colonies, but is yet unpublished. I have therefore permitted myself to enter into a more circumstantial account of these observations in this place than I have done in regard to other observers, whose works can be immediately consulted.

Mr. Douglas was furnished with a dip circle of 11½ inches in diameter, made by Dollond, with a needle on Mayer's principle; and for the intensity, with four of the same horizontal needles which I had used in 1822–1823, viz., Nos. 3, 4, 5, 6. The time of vibration of these needles was observed by Mr. Douglas in London, in 1828 and 1829, previously to his leaving England. In May, 1830, they were vibrated at Oahu, one of the Sandwich Islands; and between September, 1830, and February, 1831, at four stations in North America, where the dip was also observed, viz., Fort Vancouver, Cape Disappointment, Monterey, and St. Francisco; and at several other stations, where the dip was not observed. In February, 1831, he sent Nos. 3 and 4 to England, to have the permanency of their magnetism examined; retaining Nos. 5 and 6 with him for further observations. Nos. 3 and 4, from accidental circumstances, did not reach me till 1836 in Ireland, and being examined in Limerick and Dublin (both which stations had been carefully compared with London), No. 3 was found to have slightly gained, and No. 4 slightly lost magnetism, on a comparison with their rates in 1828 and 1829. When not employed in actual observation, these needles were kept together in the same case, with their opposite poles connected, as were Nos. 5 and 6 in another and a separate case. I have had occasion to remark elsewhere, that, when needles differing consider-

ably in their rates of vibration are so kept together, it does not unfrequently happen that the weaker needle acquires magnetism, and the stronger loses it; and such appears to have been the case in this instance. It was not until 1829 that Nos. 3 and 4 were put together, having been previously paired in a similar manner with other needles, whose magnetic strength in both cases very nearly coincided with their own. It is probable, therefore, that the one began to lose and the other to gain from that time forth; and that the whole gain or loss took place in the earlier portion, rather than equably throughout the interval from 1829 to 1836.

When needles are so kept together in pairs, the two should be employed on every occasion, and their combined result should be regarded as one determination. Mr. Douglas never employed them singly. If in such cases the gain of the one needle were exactly proportioned to the loss of the other, the results of the two needles taken separately would differ, but combined would furnish a mutual compensation. In the present case the gain and loss, though not identical, were so nearly equal, that by taking a mean between the London rates of each needle in 1829 and 1836, and combining at London and at the other stations the results of the two needles into one determination, we obtain the values of the intensity as they would have been given by a single needle whose magnetism had undergone little or no change.

The intensities thus calculated by needles 3 and 4, for the Sandwich Islands and the stations in North America, are almost identical with those computed from Nos. 5 and 6, taken jointly in the same manner, using the London rates which they had before they left England. These needles have been sought for in vain amongst Mr. Douglas's effects sent to England; their steadiness, therefore, can only be judged of from a comparison of their results with those of Nos. 3 and 4.

The special objects of Mr. Douglas's mission leading him in excursions on foot into the interior of the country, in California, and on the rivers tributary to the Columbia, the use of the horizontal needles was the only service he could there render to magnetism, as the dip circle was not sufficiently portable to be taken with him. There are 18 stations at which he used the horizontal needles alone, between $34\frac{1}{2}°$ and $54\frac{1}{2}°$ N. lat., and all nearly on the same meridian, viz., between 119° and 124° W. from Greenwich. The only absolute deduction in these cases is that of the horizontal intensity. In deducing the total force from its horizontal component, the dip employed must necessarily be computed from the dips observed at other

stations. Determinations of intensity in that part of the globe are as yet so rare, that such observations are too valuable to be omitted in this memoir; I have accordingly entered them in the general table, as well as in a separate table here, and have annexed to the latter a brief notice of the manner in which they have been computed.

The last observations recorded in Mr. Douglas's books are those which he made on the dip at Byron's Bay, and on the force, with needles 5 and 6, at Byron's Bay and in the crater of the volcano Kiraueah, soon after his arrival at Owhyhee in 1834. I have searched in vain, amongst the few loose papers which were sent home, for the rough notes of observations of very great interest, of which he speaks in his private letters, but which are not entered in his books. I mean those of the dip, variation, and intensity at the summit of Mowna Kaah, nearly 14,000 feet above the sea, and at other elevations on the island exceeding 10,000 feet. He mentions, as a general inference from these observations, that he found little or no difference between the three phænomena observed at those heights and near the sea. Those in the crater of Kiraueah, about 4000 feet above the sea (which are the only ones preserved), indicate a decidedly less intensity (1·059 to 1·098) than on the sea side at Byron's Bay, a few miles distant: but Kiraueah is a recent volcano, and no conclusion, as to the simple effect of elevation on the magnetic intensity, can of course be drawn.

In the first subjoined table are inserted the intensities determined at the stations where both the dip and horizontal intensity were observed. The second table contains those stations where the horizontal component only was observed, and the dips are supplied in the third table according to the explanation annexed to it.

Table I.

Station.	Date.	Lat.	Long. west from Greenwich	Dip observed.	Intensity. London=1·372.		
					Nos. 3 & 4.	Nos. 5 & 6.	Mean.
Fort Vancouver...	Nov., 1830...	° ′ 45 37	° ′ 122 36	° ′ 69 39·7	1·684	1·691	1·688
Cape Disappointment ...	Sept. Dec., 1830.........	46 16	123 56	69 30·3	1·668	1·679	1·674
Point George ...	....	46 11	123 40	69 16·8	....	....	....
St. Francisco......	Feb., 1831...	37 48	122 25	62 58·0	1·597	1·597	1·597
Monterey	Jan., 1831...	36 35	122 0	62 07·5	1·584	1·596	1·590
Owhyhee	Feb., 1834...	19 43	156 10	37 58·0	....	1·098	1·098

Table II.

Monterey = 1·000.		Fort Vancouver = 1·000.	
Place.	Horiz. Int.	Place.	Horiz. Int.
Stuart's Lake	0·5616	Mouth of the Wullawullah	0·9790
Frazer's Lake	0·5719	Rapids of the Columbia	1·0000
Fort Alexandria ...	0·6015	South branch of the Multnomah	1·0163
Thompson's River	0·6415	Sandiam River......	1·0463
Oakanagan	0·7165		
San F. Solano	0·9721	London = 1·000.	
San José	0·9859	Oahu..................	1·758
La Soledad	1·0056	Kiraueah	1·762
San Antonio.........	1·0080		
San Miguel	1·0101		
San Obispo	1·0222		
Santa Barbara	1·0413		
Santa Ynez	1·0335		
La Purissima	1·0282		

Table III.

Place.	Lat.	Long. west from Greenwich.	Date.	Computed dip.	Intensity London = 1·372.
Stuart's Lake	54° 27′	124° 20′	June, 1833	76° 09′	1·745
Frazer's Lake	54 03	124 40	June, 1833	75 48	1·734
Fort Alexandria	52 33	122 29	May, 1833	74 50	1·714
Thompson's River	50 41	120 11	April, 1833	73 43	1·701
Oakanagan	48 05	119 27	April, 1833	71 45	1·701
River Wullawullah	46 03	118 48	July, 1830	70 14	1·699
Rapids of the Columbia	45 40	121 48	Sept., 1830	69 27	1·671
River Multnomah	45 15	122 47	Aug., 1830	68 57	1·660
River Sandiam	44 35	122 27	Aug., 1830	68 28	1·672
St. Francisco Solano ...	38 17	122 24	July, 1831	63 24	1·614
San José	37 32	122 00	July, 1831	62 52	1·607
La Soledad	36 24	121 24	April, 1831	62 04	1·596
San Antonio...............	36 01	121 18	April, 1831	61 46	1·584
San Miguel	35 45	121 00	April, 1831	61 40	1·580
San Obispo	35 16	120 40	May, 1831	61 17	1·581
Santa Barbara	34 25	119 40	May, 1831	60 48	1·587
Santa Ynez	34 36	120 11	May, 1831	60 53	1·579
La Purissima	34 40	120 27	May, 1831	60 53	1·571
Sandwich Islands.					
Oahu........................	21 18	158 0	May, 1830	41 39	1·116
Crater of Kiraueah	19 0	....	March, 1824	38 00	1·059

The latitudes in this table, and the longitudes of the stations on the River Columbia and its tributaries are from Mr. Douglas's observations. The longitudes are chronometrical, from Fort Vancouver as a first meridian. The longitude of Fort Vancouver is computed from 1200 lunar distances observed by him. A few of these were computed on the spot, but all were fully recorded, and have been calculated since his papers arrived in England.

Notice of the manner in which the results in the above table have been computed.—There are five stations in North America at which Mr. Douglas observed the dip. The number of separate observations is 21 distributed as follows:

Cape Disappointment . . .	3
Point George	2
Fort Vancouver	6
St. Francisco	3
Monterey	7

To compute from these the dip at the eighteen stations where it was not observed, we require the direction of the isoclinal lines, and the rate at which the dip increases in the perpendicular to them.

The relative position of the five stations, being nearly on the same geographical meridian, is unfavourable for determining the direction of the lines; but, on the contrary, extremely favourable for a deduction of the rate at which the dip increases in the perpendicular to them; and as the horizontal stations are all nearly under the same meridian also, the rate of increase is the element of calculation, which it is most important to obtain correctly.

To compute, therefore, the rate of increase from the observations themselves, we may take the direction of the lines from a general map, as a small uncertainty in this respect has little influence on the result. In M. Hansteen's map of the lines of dip in 1780 we find their direction in that part of the globe to be from N. 74° W. to S. 74° E.* If we express by r the rate of increase corresponding to a geographical mile, and make $\delta =$ the dip at a central geographical position, say 45° N. lat., and 124° W. long., and δ_1, δ_2, δ_3, &c., the observed dip at the five stations, we shall have

$$\delta_1 = \delta + (a_1 \cos 74^\circ - b_1 \sin 74^\circ)\, r$$

$$\delta_2 = \delta + (a_2 \cos 74^\circ - b_2 \sin 74^\circ)\, r, \text{ \&c.,}$$

the coefficient a being the difference of longitude between the central station and that at which the dip was observed, ex-

* When I wrote the above I had not seen M. Erman's more recent magnetic map from his own observations in 1828, 1829 and 1830, in which are delineated the dip lines of 60°, 65°, and 70°, which pass through the district in which Mr. Douglas's observations were made. Their direction in the meridian of 124° W. measured on M. Erman's map is, as nearly as the measurement can be made, from N. 74½° W. to S. 74½° E. I add this note to explain the reason why the direction in the text was not taken at once from the more modern and cotemporaneous map, and to express the satisfaction I feel in this confirmation of the element I had ventured to introduce for the calculation of Mr. Douglas's results,—the only element in the calculation which was not furnished by his own observations.

pressed in geographical miles, and b the difference of latitude also in geographical miles.

If we combine the five equations so formed for the five dip stations by the method of least squares, giving each equation a weight proportioned to the number of observations which it represents, we obtain by the usual process of summing and elimination

$$\delta = 68^\circ\ 42'\ ;\ r = -\ 0{\cdot}013608,$$

the latter being equivalent to 73·5 geographical miles to one degree of dip. With these we may compute the dip for each of the horizontal stations; and having the values of the horizontal component we may deduce the total intensity. The dips and intensities for the North American stations in Table 3 are thus computed.

Mr. Douglas mentions that the dip he observed in the crater of Kiraueah was 2′ greater than at Byron's Bay; I have therefore entered it in Table 3 as 38° 00′. The dip at Oahu is from Capt. de Freycinet's observations at the adjacent island of Mowi, and must be regarded as uncertain for Oahu to some minutes; but in so low a magnetic latitude an error of that amount would have very little influence on the calculation of the intensity. The horizontal intensity at Oahu was very well determined, the four needles being employed, a few months only after their vibration in London.

Fitz Roy, 1831-1836.—We come next to a series which must rank amongst the most important contributions to magnetical science, and which we owe to Capt. Fitz Roy, R.N., and the officers of H.M. ship Beagle, employed in the years above-mentioned in the survey of the coasts of South America, and in a voyage of circumnavigation performed chiefly in the southern hemisphere, having for its primary object the determination of differences of longitude by a number of chronometers.

Capt. Fitz Roy had the precaution to furnish himself with a dipping needle of Gambey, whose instruments of this kind, though not always without fault, are universally acknowledged to be the best that are made, and superior to those of our own artists in modern times. For the intensity he received from Capt. King the horizontal needle with which that officer had been supplied by M. Hansteen. This needle, which in Capt. King's voyage had lost from time to time considerable portions of its magnetism, appears to have very nearly attained a permanent magnetic state when Capt. Fitz Roy received it. By observations at Plymouth in 1831 and 1836, and at Port Praya in 1832 and 1836, its time of vibration is shown to have varied to a very

inconsiderable amount, admitting of safe and easy interpolation.

Capt. Fitz Roy's observations are not yet published. On his return to England he paid me the compliment of placing them in my hands to calculate and arrange for publication in the appendix of an account of his voyage, which he is preparing. Meanwhile he has permitted me to insert the intensity results in the general table of this memoir. They are corrected for temperature and for arc. They include 27 stations, of which 24 in the southern hemisphere, distributed throughout its longitudes, throw very considerable light on the system of the intensity in those regions. This extensive series is, I trust, but the precursor of what British naval officers will accomplish for magnetism in the southern hemisphere.

Rudberg, 1832.—These observations were made with a dipping-needle and two horizontal needles of Gambey's, at five stations on the continent of Europe, of which Paris was one. A full account of them is published in the xxviith vol. of the *Annalen der Physik*. They appear to have been made with great care, and the results are corrected for temperature.

Lloyd and Sabine, 1835–1836.—These observations were made in compliance with a wish expressed by the British Association that some of its members would undertake a survey of the dip and intensity in the British Islands. Accordingly the intensity was determined at 30 stations in Ireland by Mr. Lloyd and myself, in 1835, and by myself at 25 stations in Scotland, in 1836. The volumes of the Reports of the British Association for those years contain a full account of these observations, as well as of the mode in which the determinations at the several stations are all made to concur in assigning the intensity at one central position in each country as their general result. It appears unnecessary, therefore, to reprint them in this volume, and it is only the intensities at the central position, thus calculated, which are entered in the general table.

Ross, 1836.—These observations were made in a voyage to Davis's Straits, undertaken by Capt. James Ross, R.N., in the winter of 1836, to relieve the crews of several whalers which had been detained in the ice. Those of the intensity were made with two horizontal needles in an apparatus similar to M. Hansteen's. The magnetism of one remained quite steady during the voyage; the other sustained a slight loss, which it is evident by inspection took place between Orkney

and Greenland, and has been allowed for accordingly; Orkney being compared with the first London rate, Greenland and Labrador with the second. The needles then give everywhere very nearly identical results.

The dip circle which Capt. Ross employed was of 4 inches diameter. The needle appears to have given very consistent results always at the same station; for example, of six observations at Westbourn-green near London in 1836, the extremes are 69° 28′ and 69° 35′·6, the poles being changed in every observation; the mean of the six, however, as well as each of the separate results, is a few minutes higher than the dip at that spot is known to have been at that time. Taking into account Capt. Ross's experience in observations of this kind, and that the observations were made on four different days, it is most probable that there was some instrumental cause for this needle giving constantly at this station a higher dip than the truth. Being ignorant, however, what that cause may have been, I have not ventured to apply a correction to the dips with this needle either there or elsewhere, but have employed them just as they were observed at each of the stations.

In countries where the dip is so great as in the vicinity of Davis's Straits, the horizontal intensities may be very correctly determined, and yet from slight errors in the dip, the resulting total intensity may present anomalies unusual elsewhere. We have an instance of this in Capt. Ross's observations in Greenland. There are two stations in Greenland, at no great distance apart, where the difference of the computed intensity is excessive; and the fact of there being some anomaly in the observed *dips* which would sufficiently explain the difference, is made quite obvious by the circumstance that the higher dip is at the southernmost station; whereas the dip should increase in going northward on this coast, and with this the horizontal vibrations are in accord. I have therefore omitted both the results in Greenland in the general table.

As these observations have not been published elsewhere, I subjoin a table containing the principal particulars.

Station.	Date.	Lat.	Long.	Time of horiz. vibra. No. 1.	Time of horiz. vibra. No. 2.	Dip observed.	Intensity London =1·372.
		° ′	° ′	s.	s.	° ′	
London......	Aug., 1835	51 31	359 50	439·07	441·46	....	1·372
Stromness...	Feb., 1836	58 58	356 30	480·22	483·34	73 36	1·419
Greenland	June, 1836	66 57	306 26	648·57	645·30	82 51	1·798
Greenland	June, 1836	68 59	306 47	667·29	665·94	82 23	1·590
Labrador ...	Aug., 1836	57 33	298 9	616·11	....	73 36	1·682
London......	Oct., 1836	51 31	359 50	442·19	441·64	69 32·1	1·372

The times of vibration are reduced to a standard temperature.

Estcourt, 1836.—These observations were made during the late survey of the navigation of the River Euphrates, conducted by Colonel Chesney. The magnetic observations were entrusted to Major Estcourt, who was furnished with a good dip circle by Robinson, and an apparatus similar to M. Hansteen's, with eight horizontal needles. Numerous observations were made with these at Port William and Bussora, the manuscripts of which have been sent to me, by the President of the Board of Control, to arrange for publication in the official account of the proceedings of the expedition, preparing under the direction of Colonel Chesney. On the arrival in England of the needles, which only took place very recently, they were also placed in my hands, in order that the necessary comparative observations might be made with them. It had unfortunately happened that the manuscript containing the times of vibration of the needles observed by the officers of the expedition before its departure from England, were on board the Tigris steamer when she was lost in the Euphrates, and no record was preserved. But on receiving the needles, I recognised two of the number as having belonged to Professor Lloyd, of Dublin, and as having been employed by Mr. Lloyd and myself in Ireland. I had consequently a memorandum of their rates before they were given to the officers of the expedition; and on vibrating them in Sussex, where I was staying when I received them, I perceived with great satisfaction that these two needles must have preserved their magnetism wholly or very nearly unaltered. They were immediately sent to Professor Lloyd, who kindly vibrated them at the same spot in which they had been used in 1834, and found their magnetism almost identical with what it had been at that period. On trying the six other needles, I found that two gave similar values for the intensity at Port William and Bussora with those of Mr. Lloyd; whence I inferred that those also had undergone no change in their magnetism since the observations on the Euphrates. The determinations at Port William and Bussora inserted in the general table of this report are derived from these four needles. Their times of vibration have been reduced to a standard temperature, the coefficient in the formula having been ascertained for each needle by experiments made since they have been placed in my hands. The full details will be communicated in Colonel Chesney's official publication.

Freycinet, 1817–1821.—I am most happy in being able to add to this collection the valuable observations of Capt. de Freycinet in the voyage of circumnavigation, performed in the

Uranie in 1817–1821. Having heard that I was engaged in drawing up this report for the British Association, Capt. de Freycinet, unsolicited, did me the honour to propose to place his observations, hitherto unpublished, in my hands, to be communicated to the public through this channel. I should certainly fail if I attempted to express my sense of this act of great liberality; happily it needs no comment; and I will only observe, that it adds another instance, but a very strong one, to those already noticed, of the good feeling that has prevailed amongst the persons by whom these inquiries have been carried forward. The world hears more than enough of the jealousies and enmities which too often disfigure the history and embitter the pursuits of science; it is right that the instances to the contrary should not always be passed in silence.

The manuscript of the observations was accompanied by the following remarks from Capt. de Freycinet.

"J'ai mis une grande attention à ce qu'il ne se glissa pas de faute dans la copie; et telle qu'elle est je crois que vous pouvez compter sur son exactitude. L'experience a prouvé que les aiguilles Nos. 7 et 8, dont je me suis servi, ont perdu un peu de leur magnétisme pendant le voyage; il sera facile d'en tenir compte, comme aussi des légères altérations qui auront eu pour cause les variations de température; mais je ne me suis pas livré à ces considérations, pensant qu'il valait mieux que vous vous en occupassiez selon vos vues particulières."

The table in pages 38 and 39 contains the observations, printed from this manuscript without alteration of any kind.

In compliance with the wish expressed by Capt. de Freycinet, I proceeded to calculate the results of these observations in the following manner. The consideration of No. 9 was put aside in the first instance for the reason assigned in the marginal note to the observations at the Isle of France. The times of vibration at Paris before and after the voyage, confirmed by the observations at Rio de Janeiro in 1817 and 1820, show that Nos. 7 and 8 both slightly lost magnetism, and No. 8 rather more than No. 7. It further appears that the extra loss of No. 8 over No. 7 was all sustained in the first fourteen months; as at the Isle of France in June, 1818, they had arrived nearly at an equality in their time of vibration, which they preserved for the whole remainder of the voyage, and exhibited on the return to Paris. In whatever way, therefore, we may proportion the *equal* loss sustained by both needles, the *extra* loss of No. 8 must be placed before the arrival at the Isle of France. When there are no circumstances in the observations

themselves indicating otherwise, the usual course is to distribute a loss equally through the interval in which it is known to have occurred. I have therefore pursued this course in regard to the loss sustained by No. 7; and in the case of No. 8 I have allowed a double proportion in each of the first fourteen months. The observations furnish two tests of the propriety of this distribution: the general agreement of the results of the two needles with each other at the different stations is one; the other is the agreement of the force thus calculated at Rio in 1817 and 1821. In both the accordance is satisfactory.

On computing the intensity at the Cape of Good Hope and the Isle of France by No. 9, using for that purpose its time of vibration at Paris in 1817, the results appeared to agree extremely well with those of Nos. 7 and 8. It is hence inferred, that until the accident at the Isle of France, No. 9 had undergone no change of magnetism, and I have therefore brought into the account all the results obtained with it before that occurrence. As the effect of changes of temperature on these particular needles does not appear to have been ascertained experimentally, no corrections are applied on account of temperature; but, as I have before remarked, such corrections are of minor importance in so extensive a series as the present. The table in page 40 exhibits the computed results, and appears to need no other explanation, except that the column entitled "Time of vibration as a dipping-needle at Paris" exhibits the times of vibration corrected for loss of magnetism.

Résumé des Observations d'Intensité Magnétique, faites pendant le Voyage de l'Uranie autour du Monde.

Localité.	Position geographique.		Epoque.		Temperature moy. centig. de l'air.	Inclinaison moyenne.	Declinaison moyenne.	Intensité magnet.		Remarques.
	Latitude.	Longitude, comptée de Paris.	Date.	Heure de l'observation d'intensité.				No. de l'aiguille observée.	Dureé de 100 oscill. infin. petites.	
Paris, avant le depart.	48° 50′ 15″ N.	0° 0′ 0″	1817 Avril 4	h 3 20′ s.	17°·95	68° 28′ 28″	22° 25′* 0″ N.O.	7	1019″·6	* Déclinaison observée en 1816.
			28	11 11 M.	8·80			7	1019·9	N.B. No. 7 a été faite exprès pour l'expedition de l'Uranie. Celle No. 8, de la même dimension a appartenu à Coulomb, et le No. 9 à MM. Humboldt et Gay Lussac. Les unes et les autres avoient une forme prismatique rectangulaire, leurs oscillations se faisaient horizontalement à l'extremité d'un fil de soie sans torsion, et à l'abri de l'air.
			Mars 30	9 4 M.	13·25			8	1009·6	
			Avril 4	4 6 s.	17·90			8	1009·6	
			28	10 32 M.	8·46			8	1010·6	
			29	11 43 M.	14·30			9	524·7	
			29	midi 19 s.	14·60			9	525·4	
Paris, au retour	*id.*	*id.*	1821 Avril 16	11 32 M.	9·5			7	1042·8	
			16	midi 33 s.	9·4			7	1044·0	
			16	1 1 s.	9·5			8	1045·3	
St. Croix de Teneriffe	28 27 57 N.	18 35 8 O.	1817 8^{bre} 26	1 30 s.	23·0	57 56 40	21 3 55 N.O.	9	450·7	
			26	2 0 s.	23·2			9	450·8	
Rio de Janeiro, 1re Relâche	22 55 1 S.	45 38 52 O.	X^{bre} 23	3 30 s.	23·0	14 42 14	2 14 40 N.E.	7	775·9	Temps orageux, tonnerres dans le N.O.
			24	8 0 M.	24·1			8	766·7	
			24	8 50 M.	26·2			8	768·2	
			24	9 30 M.	28·8			8	766·9	
			28	11 30 M.	24·3			9	402·6	
			28	midi 0	24·3			9	401·8	

			1820								
Rio de Janeiro 2ieme Relâche	22 55 25 S.	45 38 23 O.	Aout	22	1 53 s.	21·5	14 42 43	3 34 12 N.E.	8	791·2	
				22	2 13 s.	21·5			8	790·6	
				22	3 30 s.	21·5			7	790·5	
			1818								
Cap de Bonne Esperance	33 55 15 S.	16 3 45 E.	Mars	31	8 30 M.	23·0	50 47 3	26 30 31 N.O.	9	477·9	
				31	11 45 M.	27·0			8	937·0	
Ile de France (Port Louis)	20 9 56 S.	55 8 26 E.	Juin	22	midi 40	29·9	55 6 45	12 46 26 N.O.	9	468·3	
				22	2 29 s.	30·1			9	467·6	
				22	3 14 s.	28·5			9	467·5	Après cette experience No. 9 ayant été posée, par inadvertence, très près d'une de nos grands faisseaux magnétiques, s'est trouvée alterée, et a été hors de service.
				26	1 40 s.	29·0			7	912·0	
				30	1 35 s.	29·0			8	913·0	
Baie des Chiens-marins (Nlle Hollande)	25 43 21 S.	110 59 13 E.	7bre	24	11 30 M.	20·1	54 52 45	3 38 4 N.O.	8	802·5	
				24	midi 25	20·5			7	799·4	
				24	1 19 s.	21·8			7	799·5	
				24	1 40 s.	21·6			7	802·3	
Ile Timor (Coupang)	10 9 55 S.	121 15 22 E.	8bre	19	8 15 M.	29·1	32 52 3	0 13 38 N.O.	7	728·5	
				19	9 20 M.	32·6			8	729·8	
Ile Rawak (Iles des Papous)	0 1 34 S.	128 35 5 E.	Xbre	30	4 31 s.	28·2	14 26 57	1 29 52 N.E.	8	722·7	
				31	10 36 M.	29·5			7	721·6	
				31	11 26 M.	30·3			7	721·6	
			1819								
Isles Mariannes (Agagna)	13 27 51 N.	142 37 25 E.	Mai	24	4 13 s.	31·7	12 46 53	4 39 17 N.E.	8	749·9	
				25	8 4 M.	28·1			7	749·2	
				25	8 50 M.	29·1			7	749·1	
Ile Mowi (Sandwich) Raheina	20 52 7 N.	159 2 3 O.	Aout	22	11 40 M.	29·1	41 39 22	8 49 20 N.E.	8	793·0	
				22	midi 52	29·9			7	792·8	
Port Jackson (Sydney)	33 51 34 S.	148 48 0 E.	Xbre	22	10 38 M.	20·7	62 47 7	9 14 36 N.E.	7	846·4	
				22	11 47 M.	20·6			8	847·4	
Il. Malouines (Baie Française)	51 35 18 S.	60 26 52 O.	1820								
			Aout	11	1 54 s.	13·2	55 20 7	19 25 41 N.E.	7	832·2	
				11	2 44 s.	12·8			8	832·2	

Station.	Date.	Needle.	Time of vibration. Horizontal.	As a dipping-needle. At the station.	As a dipping-needle. At Paris.	Intensity. Paris = 1·000.		Paris = 1·348.
Paris	1817	7	1019·75	617·7	617·7	1·000	1·000	1·348
——	„	8	1009·93	611·7	611·7	1·000		
——	„	9	525·05	318·0	318·0	1·000		
Teneriffe	„	9	450·75	319·0	318·0	0·9942		1·340
Rio de Janeiro	„	7	775·9	763·1	620·0	0·6602	0·658	0·887
——	„	8	767·27	754·6	616·7	0·6679		
——	„	9	402·20	395·6	318·0	0·6465		
Cap de Bonne Esperance	1818	8	937·0	745·1	620·9	0·6945	0·697	0·945
——	„	9	477·9	380·0	318·0	0·7005		
Ile de France	„	7	912·0	689·7	622·8	0·8155	0·813	1·096
——	„	8	913·0	690·5	622·3	0·8139		
——	„	9	467·8	353·8	318·0	0·8082		
Baie des Chiens-marins	„	7	800·4	607·1	624·0	1·057	1·054	1·421
——	„	8	802·5	608·6	624·2	1·052		
Ile Timor	„	7	728·5	667·7	624·2	0·8741	0·873	1·177
——	„	8	729·8	668·9	624·5	0·8718		
Ile Rawak	„	7	721·6	710·1	625·1	0·7750	0·774	1·044
——	„	8	722·7	711·1	625·5	0·7736		
Iles Mariannes	1819	7	749·15	739·8	626·9	0·7181	0·718	0·968
——	„	8	749·9	740·6	627·5	0·7180		
Ile Mowi	„	7	792·8	685·3	627·9	0·8395	0·840	1·133
——	„	8	793·0	685·5	628·5	0·8401		
Sydney	„	7	846·4	572·4	629·5	1·210	1·210	1·631
——	„	8	847·4	573·1	630·3	1·210		
Iles Malouines	1820	7	832·2	627·6	630·8	1·010	1·011	1·363
——	„	8	832·2	627·6	631·5	1·012		
Rio de Janeiro	„	7	790·5	777·5	632·2	0·6612	0·662	0·892
——	„	8	790·9	777·8	633·6	0·6625		
Paris	1821	7	1043·4	635·1	635·1	1·000	1·000	1·348
——	„	8	1045·3	636·3	636·3	1·000		

It would have given me great satisfaction had I been enabled to have included in this publication the observations made in India by Capt. Jules de Blosseville, in whose untimely death within the Arctic circle, now, I fear, but too certain, science has sustained the loss of an officer who gave full promise, had he lived, of becoming one of the most accomplished navigators of the age. In the last letter which I received from him, dated at Toulon in 1830, he thus expresses himself in regard to his observations of the intensity :—" Toulon ayant été, et pouvant devenir encore le point de départ de plusieurs expeditions scienifiques, il sérait utile, je pense, d'y connoître d'une manière exacte la valeur de l'intensité magnétique, et je me chargerais

volontiers pendant le petit sejour que je vais y faire, d'y observer les aiguilles. Ceci me conduit naturellement à vous parler des observations d'intensité que vous m'avez vues commencer à Paris, et que j'ai faites ensuite dans plusieurs lieux de l'Inde. Si elles avaient été plus satisfaisantes, je vous en aurais entretenu dès mon arrivée; mais malheureusement les aiguilles ont perdu pendant le voyage une partie notable de leur magnétisme, et M. Arago a été d'avis de ne point s'occuper de leurs résultats. C'est ainsi que toutes mes peines ont été perdues, quoique j'eusse eu l'attention de rapporter toutes les observations à Pondicherry, qui était le centre de nos operations, espérant par leur repetition dans le même lieu, connoître le decroissement graduel du magnétisme de nos aiguilles. Si je recommence quelque grand voyage, comme je l'espère, je me livrerai avec plaisir à l'étude de l'intensité, et je m'occuperai à l'avance, de faire faire par Gambey l'appareil de plus commode. Je voudrais connoître vos idées sur ce sujet."

Experience has shown in many cases, and particularly in the observations of Capt. King, that it may be possible to obtain very valuable facts from a series of observations, in which the needles have undergone a considerable loss of magnetism in the course of a long voyage; particularly in cases where attention has been paid to repetition at the same station, for the purpose of a frequent examination of the state of the needles; and this was practised by Capt. de Blosseville, as well as by Capt. King. Aid may also be sometimes obtained from other observers who may have observed the intensity at some of the stations: and the publication of a series of determinations depending upon Pondicherry would render it an object with persons who might hereafter be engaged in magnetic observations in India, to make Pondicherry one of their stations, and thus supply a link to connect M. de Blosseville's observations with Europe.

In 1833 Mr. Forbes made a very numerous series of excellent determinations of horizontal intensity in different parts of Europe. They were made chiefly with a view to the influence of height on the magnetic intensity, and are discussed in a highly interesting paper in the Edinburgh Transactions for 1836. The dip was observed with a three-inch circle, at a few stations only, and Mr. Forbes has nowhere himself deduced the total intensities. If I am rightly informed, he has since made another tour in the same countries, in which magnetic observations formed a part of his object. We may hope that by a series of dips, corresponding in extent and exactness to his horizontal determinations, he will add greatly to the fulness

and accuracy of our knowledge of the course of the magnetic lines in those parts of Europe. The investigation evidently cannot be in better hands. Meantime I have not thought proper to make deductions which he has not made for himself; and the more so, because the stations are very few at which there are both observations of dip and of horizontal intensity, and at some of these the total intensity has already been determined by other observers.

The preceding notices include all the observations of the magnetic intensity with which I am acquainted, in which the instruments, by the steadiness of their magnetism, and their capability of yielding sufficiently precise results, proved worthy of the time and pains bestowed in their employment.

Section II.—General Table of Intensities.

The intensities are arranged in this table according to their values, commencing with those of highest amount in the northern hemisphere, descending progressively to those of least amount, which have their places in the intertropical regions, and again ascending to the highest values in the southern hemisphere. They are classed in zones, the first zone (§ 1) comprehending all the observed intensities in the northern hemisphere between 1·85 and 1·75; the second zone (§ 2), all between 1·75 and 1·65; the third (§ 3), all between 1·65 and 1·55; and so on. In each zone the record in the table commences with the geographical meridian of Greenwich, and passes round the globe in an easterly direction; all the longitudes being counted east from Greenwich, and all latitudes north, unless where it is otherwise distinctly specified.

The geographical position of the several zones is shown in the maps attached to this report by the insertion of the observed intensities themselves in their places in the map. For the more ready guidance and direction of the eye lines are drawn, marking as nearly as can be judged, the middle of each zone. These lines are consequently what are usually denominated isodynamic lines, or lines of equal magnetic intensity at the surface of the earth. They correspond successively to the values of 1·8, 1·7, 1·6, &c., down to 0·8, which is the line of lowest value yet observed. There is, of course, great inequality in the evidence for their precise geographical position in different parts of the globe; sometimes, for the purpose of connection, they have been partially continued where obser-

vations are wholly wanting; but in all cases the insertion of the authorities themselves in the map manifests the degree of exactness to which it is yet possible to trace the several portions of each line.

Where the geographical positions are too near each other for convenient insertion in the map, two or more stations are collected into a group in the table, and the mean latitude, longitude, and intensity are placed at the foot of the page. Such groups are in all cases composed of the determinations of the same observer, and the mean determination inserted in the map is characterised by an additional figure, placed beneath, expressive of the number of separate stations thus represented.

In the case of stations visited by two or more observers, their separate determinations have been inserted in the map wherever space has permitted. As this could not always be done in the north of Europe and Asia, the mean of the determinations of the two observers has been given, characterised by the mark +, expressive of the double weight to which such intensities are entitled.

The geographical positions may require correction in a few instances, but pains have been taken to obtain them correctly from the most recent authorities.

Division I. Northern Hemisphere.

§ 1. *Intensities from* 1·85 *to* 1·75.

Station.	Lat.	Long.	Observer.	Date.	Intensity.
Viluisk	63° 0′	120° 0′	Due...............	1829	1·759
New York	40 43	285 57	Sabine............	1822	1·803

§ 2. *Intensities from* 1·75 *to* 1·65.

Station.	Lat.	Long.	Observer.	Date.	Intensity.
Turuchansk	65 55	87 33	Hansteen..........	1829	1·667
Sebrinikowo	60 02	90 33	Hansteen..........	1829	1·660
Atschinsk	56 16	91 00	Hansteen & Due....	1828	1·654
Jenesiek..........	58 27	92 11	Hansteen..........	1829	1·668
Krasnojarsk	56 01	92 57	Erman.............	1829	1·652
„	„	„	Hansteen & Due....	1829	1·663
Kansk............	55 43	96 53	Erman.............	1829	1·670
„	„	„	Hansteen & Due....	1829	1·678
Kamyochatsk......	55 12	98 50	Hansteen & Due....	1828	1·671
N. Udinsk	55 00	99 20	Hansteen & Due ...	1828	1·672

Station.	Lat.	Long.	Observer.	Date.	Intensity.
	° ′	° ′			
Kurgan	54 20	100 00	Erman	1829	1·652
Salarinsk	53 30	102 00	Hansteen & Due ..	1828	1·652
Sawaria	53 34	101 53	Erman	1829	1·657
Olonska	52 59	105 04	Erman	1829	1·673
Botowsk..........	55 10	105 22	Erman	1829	1·720
Bojarsk	56 05	105 34	Erman	1829	1·689
Tarakanowa	52 14	106 37	Erman	1829	1·664
Potapowsk	57 17	107 34	Erman	1829	1·711
Kirensk	57 47	108 04	Due	1829	1·704
"	"	"	Erman	1829	1·693
Itschora..........	58 38	109 36	Erman	1829	1·714
Ivanofska	58 38	110 34	Due	1829	1·708
Parchinsk	59 07	111 31	Erman	1829	1·741
Wittinsk..........	59 40	112 00	Due	1829	1·731
Kantinsk	59 53	114 10	Due	1829	1·712
"	"	"	Erman	1829	1·733
Jarbinsk..........	60 28	116 15	Erman	1829	1·702
Beresowsk	59 50	117 56	Erman	1829	1·747
Olekma	60 22	119 33	Due	1829	1·725
"	"	"	Erman	1829	1·707
Sanjacktatsk	60 47	123 46	Erman	1829	1·732
Toen Arinsk	61 37	128 31	Erman	1829	1·689
Yakutsk	62 01	129 45	Erman	1829	1·697
Porotowsk	62 01	131 50	Erman	1829	1·721
Lebeghine	62 11	133 42	Erman	1829	1·697
Nokchinsk	61 57	134 57	Erman	1829	1·713
Perewos	61 45	135 40	Erman	1829	1·679
Tchernolies } *	61 31	136 23	Erman	1829	1·700
Karnastak }	61 30	137 00	Erman	1829	1·690
Allachjan	61 03	138 45	Erman	1829	1·678
Judomsk..........	60 54	140 35	Erman	1829	1·680
Arki	60 07	142 20	Erman	1829	1·644
Bay of St. Lawrence	65 38	189 14	Lütke............	1828	1·652
At Sea	48 44	216 37	Lütke............	1827	1·653
Sitka	57 03	224 44	Lütke............	1827	1·735
"	"	"	Erman	1829	1·726
Frazer's Lake......	54 03	235 20	Douglas	1833	1·724
Stuart's Lake	54 27	235 40	Douglas	1833	1·736
Cape Disappointment	46 16	236 04	Douglas	1830	1·674
Fort Alexandria....	52 33	237 31	Douglas	1833	1·710

* Mean, 2 stations 61 30 137 00 1·695

Station.	Lat.	Long.	Observer.	Date.	Intensity.
	° ′	° ′			
*Multnomah River	45 15	237 13	Douglas	1830	1·669
*Fort Vancouver..	45 37	237 24	Douglas	1830	1·688
*Sandiam River ..	44 35	237 33	Douglas	1830	1·683
*Columbia Rapids	45 40	238 12	Douglas	1830	1·679
Thompson's River..	50 41	239 49	Douglas	1833	1·710
Oakanagan........	48 05	240 33	Douglas	1833	1·707
Wullawullah River .	46 03	241 12	Douglas	1830	1·707
Byam Martin's Il. ..	75 10	256 16	Sabine	1819	1·653
Regent's Inlet......	72 45	270 19	Sabine	1819	1·668
Baffin's Bay	76 08	281 39	Sabine	1818	1·659
Baffin's Bay	76 45	284 00	Sabine	1818	1·666
Baffin's Bay	70 35	293 05	Sabine	1818	1·661
Labrador	57 33	298 09	Ross	1836	1·682

§ 3. *Intensities from* 1·65 *to* 1·55.

Spitzbergen, Fairhaven	79 40	11 40	Sabine	1823	1·562
Spitzbergen, South Cape	76 35	14 00	Keilhau	1827	1·558
Katchegatisk	65 09	65 02	Erman	1828	1·568
Beresow	63 56	65 04	Erman	1828	1·580
Kunduwaski	63 18	65 06	Erman	1828	1·584
Wandiask	66 16	65 10	Erman	1828	1·608
Kondinsk	62 13	66 36	Erman	1828	1·596
Obdorsk..........	66 31	66 42	Erman	1828	1·580
Jugakow..........	57 32	67 06	Erman	1828	1·546
,, ...	,,	,,	Hansteen & Due ..	1828	1·558
Chutarbitka	57 59	67 31	Erman	1828	1·544
,, ...	,,	,,	Hansteen & Due ..	1828	1·566
Kewaskirche	61 20	68 05	Erman	1828	1·585
Tobolsk	58 12	68 16	Hansteen & Due ..	1828	1·560
,, ...	,,	,,	Erman	1828	1·554
Samarowo	60 45	68 35	Erman	1828	1·584
Uwatsk	59 00	68 46	Erman	1828	1·564
Kolotschikowo	57 27	68 58	Erman	1829	1·564
Sawotinski........	60 23	69 26	Erman	1828	1·573
Tugalowsk........	59 32	69 40	Erman	1828	1·574
Tara	56 54	74 04	Erman	1829	1·575
Pokrowsk	55 38	77 05	Erman	1829	1·617

* Mean, 4 stations 45° 17′ 237° 35′ 1·680

Station.	Lat.	Long.	Observer.	Date.	Intensity.
Muraschiwa	55 50	76 00	Hansteen & Due ..	1828	1·586
Gotoputowa	55 47	77 00	Hansteen & Due ..	1828	1·577
Autoschina........	55 40	78 00	Hansteen & Due ..	1828	1·585
Kainsk	55 40	78 10	Hansteen & Due ..	1828	1·601
Narym	58 50	81 00	Due	1828	1·638
Tschulum	55 06	81 14	Erman	1829	1·578
Kolyvan..........	55 17	82 45	Hansteen & Due ..	1829	1·611
"	"	"	Erman	1829	1·599
Togursk..........	58 40	83 00	Due	1828	1·644
Barnaul	53 20	83 56	Hansteen	1829	1·605
Tomsk	56 30	85 09	Erman	1829	1·618
"	"	"	Hansteen & Due ..	1829	1·620
Pojelnik..........	56 18	87 10	Erman	1829	1·627
Kangatovo........	63 27	87 16	Hansteen	1829	1·648
Irkutsk	52 16	104 20	Hansteen & Due ..	1829	1·642
"	"	"	Erman	1829	1·632
Kadilna	52 07	104 51	Hansteen & Due ..	1829	1·649
"	"	"	Erman	1828	1·634
Chogotsk	53 00	105 00	Due	1829	1·645
Tiumeruska	54 09	105 33	Erman	1828	1·648
Selenginsk........	51 20	106 15	Hansteen & Due ..	1829	1·642
Troisko Sawsk	50 21	106 28	Hansteen & Due ..	1829	1·642
"	"	"	Erman	1829	1·628
Monachorowa	50 58	106 29	Hansteen & Due ..	1829	1·624
"	"	"	Erman	1829	1·638
Arsentiska........	51 17	106 56	Hansteen & Due ..	1829	1·650
"	"	"	Erman	1829	1·636
Werchne Udinsk ..	51 49	107 47	Hansteen and Due..	1829	1·625
" ..	"	"	Erman	1829	1·626
Ochozk	59 21	143 11	Erman	1829	1·615
Sea of Ochozk	58 46	145 52	Erman	1829	1·677
Sea of Ochozk	58 15	152 01	Erman	1829	1·601
Sea of Ochozk	58 13	157 06	Erman	1829	1·595
Tigil River........	58 01	158 15	Erman	1829	1·577
Maschura	55 04	158 55	Erman	1829	1·551
St. Croix Bay......	65 28	181 28	Lütke...........	1828	1·646
Unalaska	53 54	193 30	Lütke...........	1827	1·604
St. Francisco......	37 48	235 45	Erman	1829	1·585
"	"	"	Douglas..........	1831	1·597
* San Solano......	38 17	235 36	Douglas..........	1831	1·610
* Monterey	36 35	236 00	Douglas..........	1831	1·599
* San José	37 32	236 00	Douglas..........	1831	1·605
* La Soledad	36 24	236 36	Douglas..........	1831	1·590
* Mean, 4 stations	37 12	236 03			1·600

Lat. and Long. in degrees and minutes (° ′).

	Station.	Lat.	Long.	Observer.	Date.	Intensity.
*	San Antonio	36° 01′	236° 42′	Douglas	1831	1·584
*	San Miguel	35 45	237 16	Douglas	1831	1·583
*	St. Louis Obispo .	35 16	237 20	Douglas	1831	1·583
†	La Purissima....	34 40	237 33	Douglas	1831	1·571
†	Santa Ynez	34 36	237 49	Douglas	1831	1·579
†	Santa Barbara ..	34 25	240 00	Douglas	1831	1·604
	Melville Island	74 27	248 18	Sabine	1819	1·624
	Winter Harbour ..	74 47	249 12	Sabine	1820	1·638
	Possession Bay	73 31	282 38	Sabine	1819	1·637
	Baffin's Bay	75 51	296 54	Sabine	1818	1·618
	Davis's Straits	64 00	298 10	Sabine	1819	1·621
	Baffin's Bay	75 05	299 37	Sabine	1818	1·590
	Hare Island	70 26	305 08	Sabine	1818	1·622
	Davis's Straits	68 22	306 10	Sabine	1818	1·643

§ 4. *Intensities from* 1·55 *to* 1·45.

	Station.	Lat.	Long.	Observer.	Date.	Intensity.
	Slidre............	61 05	8 09	Hansteen	1821	1·454
	Idsat	62 57	11 18	Hansteen	1825	1·452
	Bodoe............	67 15	13 55	Keilhau	1827	1·451
	Bear Island	74 55	14 50	Keilhau	1827	1·496
	Spitzbergen, Whale's Head ..	77 25	17 00	Keilhau	1827	1·539
‡	Tromsoe	69 38	18 55	Keilhau	1827	1·515
‡	Jacob's Elv	69 54	20 45	Keilhau	1827	1·467
‡	Talvig	70 02	22 48	Keilhau	1827	1·512
‡	Havoe Sund	70 57	23 19	Keilhau	1827	1·476
‡	Ingoe..........	71 06	24 03	Keilhau	1827	1·517
‡	Mageroe	71 01	26 01	Keilhau	1827	1·500
	Hammerfest	70 40	23 46	Sabine	1823	1·506
	,, ...	,,	,,	Keilhau	1827	1·461
	Upper Tornea	66 16	23 47	Hansteen	1825	1·464
	Brahestad	64 41	24 20	Hansteen	1825	1·455
§	Lebbesbye......	70 37	26 45	Keilhau	1827	1·465
§	Mehavn........	71 06	27 53	Keilhau	1827	1·496
§	Kaleboton	70 12	28 10	Keilhau	1827	1·491
§	Omgang........	71 00	28 30	Keilhau	1827	1·487
§	Berlevaag	70 54	29 11	Keilhau	1827	1·460
§	Wadsoe	70 10	29 50	Keilhau	1827	1·469

	Lat.	Long.	Intensity.
* Mean, 3 stations	35° 41′	237° 06′	1·583
† Mean, 3 stations	34 34	238 27	1·585
‡ Mean, 6 stations	70 26	22 38	1·498
§ Mean, 6 stations	70 40	28 23	1·478

Station.	Lat.	Long.	Observer.	Date.	Intensity.
Wardhuus	70° 23′	31° 07′	Keilhau	1827	1·477
Miteschka	56 13	49 54	Erman	1828	1·459
,, ...	,,	,,	Hansteen & Due....	1828	1·447
Milet	56 41	50 30	Erman	1828	1·473
,, ...	,,	,,	Hansteen & Due....	1828	1·461
Koschil	57 08	51 52	Erman	1828	1·488
,, ...	,,	,,	Hansteen & Due....	1828	1·478
Suri	57 34	53 23	Erman	1828	1·476
,, ...	,,	,,	Hansteen & Due....	1828	1·477
Dubrowa	57 42	54 30	Erman	1828	1·482
,, ...	,,	,,	Hansteen & Due....	1828	1·488
Ochansk	57 00	56 00	Hansteen & Due....	1828	1·497
Perm	58 01	56 14	Hansteen & Due....	1828	1·494
,, ...	,,	,,	Erman	1828	1·489
Krilassowa........	57 34	56 37	Hansteen & Due....	1828	1·501
,, ...	,,	,,	Erman	1828	1·535
Buikowa..........	56 53	57 26	Hansteen & Due....	1828	1·504
,, ...	,,	,,	Erman	1828	1·514
Kirgischansk	56 50	59 06	Hansteen & Due....	1828	1·525
,, ...	,,	,,	Erman	1828	1·509
Kushwa	58 17	59 43	Hansteen & Due....	1828	1·500
,, ...	,,	,,	Erman	1828	1·502
N. Tagilsk	57 55	59 54	Hansteen & Due....	1828	1·506
Bogoslowsk	59 49	59 55	Erman	1828	1·524
,, ...	,,	,,	Hansteen & Due....	1828	1·509
Ekaterinenburg....	56 51	60 34	Erman	1828	1·522
,, ...	,,	,,	Hansteen & Due....	1828	1·524
Werchoturie	58 52	60 46	Erman	1828	1·548
,, ...	,,	,,	Hansteen & Due....	1828	1·536
Bjelieska..........	56 50	61 56	Erman	1828	1·509
,, ...	,,	,,	Hansteen & Due....	1828	1·508
Sugazk	57 00	63 44	Erman	1828	1·501
,, ...	,,	,,	Hansteen & Due....	1828	1·535
Tiumen	57 10	65 27	Erman	1828	1·505
,, ...	,,	,,	Hansteen & Due....	1828	1·550
Nishnei Turinsk....			Hansteen & Due....	1828	1·535
Orlowa			Hansteen & Due....	1828	1·543
Semipalatinsk......	50 24	80 21	Hansteen	1829	1·556
Natschika	53 06	158 15	Erman	1829	1·494
St. Peter and St. Paul	53 00	158 40	Erman	1829	1·489
Kosuirewsk	55 52	159 34	Erman	1829	1·548
Chartschinsk	56 31	160 43	Erman	1829	1·542
Ielowka	56 54	160 55	Erman	1829	1·543
Kuruginski........	58 34	163 27	Lütke	1828	1·533
At Sea	40 28	213 35	Lütke	1827	1·456

Station.	Lat.	Long.	Observer.	Date.	Intensity.
Cayman Island	19° 14′	278° 55′	Sabine............	1822	1·450
Terceira...........	38 39	332 47	Fitz Roy..........	1836	1·457
Greenland	74 32	341 10	Sabine............	1823	1·543

§ 5. *Intensities from* 1·45 *to* 1·35.

Brussels	50 52	4 20	Quetelet	1829	1·374
"	"	"	Rudberg	1832	1·369
Bekkervig	60 01	5 10	Hansteen..........	1821	1·411
Bergen	60 24	5 17	Hansteen..........	1821	1·422
* Ullensvang	60 20	6 38	Hansteen..........	1821	1·426
Leierdal........	61 10	7 50	Hansteen..........	1821	1·419
Mariasteen......	61 02	8 14	Hansteen..........	1821	1·406
Norsteboe	60 20	8 37	Hansteen..........	1821	1·414
Francfort	50 10	8 37	Quetelet	1829	1·358
Tubingen	48 31	9 04	Humboldt & G. Lussac	1806	1·357
Ingolfsland	59 53	8 48	Hansteen..........	1821	1·416
Bolkesjoë	59 43	9 20	Hansteen..........	1821	1·405
† Korset	58 49	9 32	Hansteen..........	1822	1·373
Kongsberg......	59 40	9 40	Hansteen..........	1820	1·414
Helgeroe	58 59	9 54	Hansteen..........	1822	1·398
Kolding	55 27	9 20	Hansteen..........	1824	1·385
Sleswig	54 31	9 55	Hansteen..........	1824	1·381
Gottingen	51 32	9 55	Humboldt & G. Lussac	1806	1·348
"	"	"	Quetelet	1829	1·365
"	"	"	Rudberg	1832	1·349
Aalborg	57 03	9 56	Hansteen..........	1824	1·367
Tomlevold......	60 51	9 58	Hansteen..........	1821	1·425
Heggen	59 55	10 10	Hansteen..........	1825	1·415
‡ Drammen	59 49	10 13	Hansteen..........	1823	1·377
Moe	60 14	10 31	Hansteen..........	1821	1·423
Gran	60 22	10 32	Hansteen..........	1821	1·422
Johnsrud	59 57	10 37	Hansteen..........	1825	1·425
Aarhuus..........	56 10	10 14	Hansteen..........	1824	1·384
Odense	55 24	10 19	Hansteen..........	1824	1·365
Drontheim........	63 26	10 25	Sabine............	1823	1·442
"	"	"	Hansteen..........	1825	1·430
Christiania	59 55	10 45	Hansteen..........	1820	1·419

* Mean, 6 stations	60° 33′	7° 38′	1·416
† Mean, 5 stations	59 13	9 27	1·401
‡ Mean, 6 stations	60 11	10 20	1·414

	Station.	Lat.	Long.	Observer.	Date.	Intensity.
*	Elleöen	59° 19′	10° 40′	Hansteen	1822	1·384
*	Soner	59 32	10 45	Hansteen	1822	1·383
*	Skieberg	59 14	11 11	Hansteen	1822	1·372
*	Fredericshall	59 01	11 30	Hansteen and Due	1828	1·387
*	Altorp	58 53	12 14	Hansteen	1822	1·389
†	Vang	61 06	10 34	Hansteen	1821	1·431
†	Nebye	62 18	10 58	Hansteen	1825	1·423
†	Biornestad	61 03	11 28	Hansteen	1825	1·423
†	Roraas	62 34	11 35	Hansteen	1825	1·440
†	Grundsat	60 56	11 35	Hansteen	1825	1·440
‡	Fredericshavn	57 27	10 33	Hansteen	1824	1·384
‡	Gottenburg	57 42	10 58	Hansteen	1819	1·383
‡	Quistrum	58 27	11 45	Hansteen	1819	1·407
‡	Odensala	57 26	12 03	Hansteen	1822	1·367
‡	Wennersborg	58 22	12 17	Hansteen & Due	1828	1·381
	Suul	63 42	12 12	Hansteen	1825	1·423
§	Soroe	55 27	11 54	Hansteen	1820	1·384
§	Fredericsberg	55 56	12 18	Hansteen	1820	1·403
§	Helsingberg	56 03	12 43	Hansteen	1820	1·378
§	Copenhagen	55 41	12 55	Hansteen	1820	1·367
	Leipsic	51 20	12 22	Keilhau & Boeck	1826	1·359
	„	„	„	Quetelet	1829	1·363
	Magnor	59 57	12 22	Hansteen	1825	1·420
	Berlin	52 31	13 22	Humboldt & G. Lussac	1806	1·370
	„	„	„	Erman	1828	1·367
	„	„	„	Quetelet	1829	1·367
	Dresden	51 02	13 43	Quetelet	1829	1·366
	Ystad	55 26	13 56	Erichsen	1824	1·374
‖	Carlstad	59 23	13 26	Hansteen	1825	1·378
‖	Mariestad	58 40	13 50	Hansteen & Due	1828	1·381
‖	Lincoping	58 26	15 38	Hansteen & Due	1828	1·356
	Carolath	51 46	15 57	Erichsen	1824	1·351
¶	Oestersund	63 10	14 32	Hansteen	1825	1·434
¶	Grimnas	62 50	15 10	Hansteen	1825	1·427
¶	Alsta	62 29	16 0	Hansteen	1825	1·422
¶	Sundswall	62 22	17 16	Hansteen	1825	1·415
¶	Hernosand	62 38	17 53	Hansteen	1825	1·421

	Lat.	Long.	Intensity
* Mean, 5 stations	59° 12′	11° 16′	1·383
† Mean, 5 stations	61 35	11 16	1·431
‡ Mean, 5 stations	57 53	11 31	1·384
§ Mean, 4 stations	55 47	12 28	1·383
‖ Mean, 3 stations	58 50	14 18	1·372
¶ Mean, 5 stations	62 42	16 10	1·424

Station.	Lat.	Long.	Observer.	Date.	Intensity.
Gebostad	59° 15′	17° 50′	Keilhau	1827	1·444
Stockholm	59 20	18 04	Hansteen..........	1825	1·392
"	"	"	Hansteen & Due....	1828	1·386
"	"	"	Erman............	1828	1·386
"	"	"	Rudberg	1832	1·382
Dantzic	54 21	18 38	Erichsen	1824	1·374
Umea............	63 49	20 12	Hansteen..........	1825	1·413
Königsberg	54 43	20 30	Erman............	1826	1·365
Tjock............	62 17	21 22	Hansteen..........	1825	1·406
Pitea	65 19	21 29	Hansteen..........	1825	1·448
Wasa	63 04	21 42	Hansteen..........	1825	1·448
Biorneborg........	61 29	21 46	Hansteen..........	1825	1·400
Abo	60 27	22 18	Hansteen..........	1825	1·389
Carleby	63 38	22 51	Hansteen..........	1825	1·414
Tornea	65 50	24 15	Hansteen..........	1825	1·445
Uleaborg	65 00	25 30	Hansteen..........	1825	1·440
Petersburg........	59 56	30 18	Hansteen & Due....	1828	1·410
Pomeranja........	59 13	31 23	Erman............	1828	1·427
"	"	"	Hansteen & Due....	1828	1·417
G. Novgorod......	58 31	31 19	Erman............	1828	1·412
"	"	"	Hansteen & Due....	1828	1·412
Waldai	57 55	33 10	Erman............	1828	1·416
"	"	"	Hansteen & Due....	1828	1·416
W. Wolotschok	57 35	34 40	Erman............	1828	1·417
"	"	"	Hansteen & Due....	1828	1·395
Tver	56 52	35 57	Erman............	1828	1·398
"	"	"	Hansteen & Due....	1828	1·397
Moscow	55 46	37 36	Erman............	1828	1·408
"	"	"	Hansteen & Due....	1828	1·401
Platowa	55 41	38 35	Hansteen & Due....	1828	1·399
"	"	"	Erman............	1828	1·411
Demitrewski	55 59	39 59	Hansteen & Due....	1828	1·409
"	"	"	Erman	1828	1·463
Murom	55 35	41 12	Hansteen & Due....	1828	1·436
"	"	"	Erman............	1828	1·433
Osablikowo	55 54	42 26	Hansteen & Due....	1828	1·423
Doskino..........	56 09	43 34	Erman............	1828	1·434
"	"	"	Hansteen & Due....	1828	1·400
N. Novgorod	56 19	43 57	Erman............	1828	1·442
"	"	"	Hansteen & Due....	1828	1·408
Tschougouniei	56 06	45 48	Erman............	1828	1·435
"	"	"	Hansteen & Due....	1828	1·431
Angikowo	55 44	48 09	Erman............	1828	1·450
"	"	"	Hansteen & Due....	1828	1·428

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Station.	Lat.	Long.	Observer.	Date.	Intensity.
Kasan............	55 48	49 07	Erman............	1828	1·440
"	"	"	Hansteen & Due....	1828	1·425
Uralsk	51 11	51 22	Hansteen..........	1829	1·398
Klinen	49 05	52 00	Hansteen..........	1829	1·370
Orenburg	51 45	55 06	Hansteen..........	1829	1·432
Oufa	54 45	56 00	Hansteen..........	1829	1·469
Havana	23 09	277 38	Humboldt	1801	1·351
"	"	"	Sabine............	1822	1·492
Jamaica	17 56	283 06	Sabine............	1822	1·436
Madeira	32 38	343 04	Sabine............	1822	1·373
"	"	"	King	1826	1·377
Ireland. By 30 stations	53 25	352 05	Lloyd & Sabine	1835	1·410
Scotland. By 25 stations	56 27	355 35	Sabine............	1836	1·414
Stromness	58 58	356 30	Ross..............	1836	1·419
Brassa............	60 09	358 48	Sabine............	1818	1·443
London	51 31	359 50	Sabine............	1827	1·372

§ 6. *Intensities from* 1·35 *to* 1·25.

Station.	Lat.	Long.	Observer.	Date.	Intensity.
* Valencia	39 29	359 36	Humboldt	1798	1·241
* Cambrils	40 55	0 46	Humboldt	1798	1·305
* Barcelona	41 23	2 12	Humboldt	1798	1·348
* Gerona	41 52	2 48	Humboldt	1798	1·209
* Perpignan	42 43	2 57	Humboldt	1798	1·381
Paris	48 52	2 21	Humboldt	1800	1·348
† Montpellier	43 36	3 53	Humboldt	1798	1·348
† Nismes	43 50	4 20	Humboldt	1798	1·294
† Marseilles	43 18	5 23	Humboldt	1798	1·294
‡ Lyons	45 46	4 52	Humboldt & G. Lussac	1805	1·333
‡ St. Michel	45 23		Humboldt & G. Lussac	1805	1·349
‡ M. Cenis	45 14	6 55	Humboldt & G. Lussac	1805	1·344
§ Geneva	46 12	6 07	Quetelet	1830	1·292
§ Gd. St. Bernard..	45 55	7 11	Quetelet	1830	1·294
Lanslebourg	45 18		Humboldt & G. Lussac	1805	1·323

	Lat.	Long.	Intensity
* Mean, 5 stations	41° 16′	1° 39′	1·296
† Mean, 3 stations	43 35	4 32	1·312
‡ Mean, 3 stations	45 28	5 53	1·342
§ Mean, 2 stations	46 03	6 39	1·293

	Intensity.	Lat.	Long.	Observer.	Date.	Intensity.
*	Turin	45° 04′	7° 42′	Humboldt & G. Lussac	1805	1·336
*	St. Gothard	46 32	8 33	Humboldt & G. Lussac	1805	1·314
*	Altorp	46 41	8 32	Humboldt & G. Lussac	1805	1·325
*	Como	45 48	9 06	Humboldt & G. Lussac	1805	1·310
	Milan	45 28	9 09	Humboldt & G. Lussac	1805	1·312
	"	"	"	Quetelet	1830	1·294
	Florence..........	43 46	11 15	Humboldt & G. Lussac	1805	1·278
	Munich	48 08	11 34	Erman	1826	1·339
	Rome	41 54	12 26	Humboldt & G. Lussac	1805	1·264
	Toplitz	49 58	12 52	Keilhau & Boeck ..	1826	1·334
†	Trieste	45 38	13 47	Keilhau & Boeck ..	1826	1·317
†	Lohitsch	45 55	14 13	Keilhau & Boeck ..	1826	1·314
	Naples	40 50	14 14	Humboldt & G. Lussac	1805	1·274
	Prague	50 05	14 27	Keilhau	1826	1·332
‡	Gratz..........	47 04	15 27	Keilhau & Boeck	1826	1·327
‡	Iglau	49 23	15 36	Keilhau & Boeck	1826	1·319
‡	Vienna	48 13	16 23	Keilhau & Boeck	1826	1·325
	Nicolaieff	46 58	32 01	Kupffer	1829	1·275
	Taganrog	47 12	38 58	Kupffer	1829	1·308
	Stavropol	45 03	42 01	Kupffer	1829	1·327
	Bridge of Malka ..	43 45	42 30	Kupffer	1829	1·302
	Astrachan	46 20	48 00	Hansteen..........	1830	1·334
	At Sea	13 39	311 50	Humboldt	1799	1·256
	At Sea	20 41	335 08	Humboldt	1799	1·256
	Teneriffe..........	28 27	343 45	Humboldt	1798	1·272
	"	"	"	Freycinet..........	1817	1·340
	"	"	"	Sabine	1822	1·313
§	Ferrol	43 29	351 46	Humboldt	1799	1·262
§	Villa el Pando ..	41 58	354 33	Humboldt	1799	1·294
§	Medina del Campo	41 24	355 16	Humboldt	1799	1·294
§	Guadarama	40 39	355 52	Humboldt	1799	1·294
§	Villa Franca	42 37	355 59	Humboldt	1799	1·294
§	Madrid	40 25	356 19	Humboldt	1799	1·294

* Mean, 4 stations	46° 00′	8° 28′	1·321
† Mean, 2 stations	45 45	14 00	1·315
‡ Mean, 3 stations	48 13	15 49	1·324
§ Mean, 6 stations	41 45	354 58	1·290

§ 7. *Intensities from* 1·25 *to* 1·15.

Station.	Lat.	Long.	Observer.	Date.	Intensity.
Port William	37° 00′	38° 00′	Estcourt	1836	1·198
Bussora	30 20	47 36	Estcourt	1836	1·175
At Sea	39 07	159 03	Lütke	1827	1·186
Carthagena	10 25	285 31	Humboldt	1801	1·294
* Mompox	9 14	285 34	Humboldt	1801	1·199
Morales	8 15	286 0	Humboldt	1801	1·188
Nueva Valencia	10 10	291 47	Humboldt	1800	1·127
Hac. de Cura	10 16	292 06	Humboldt	1800	1·189
Victoria	10 14	292 30	Humboldt	1800	1·251
† Hac. de Tui	10 17	292 34	Humboldt	1800	1·168
Venta di Avila	10 33	292 53	Humboldt	1800	1·230
La Guayra	10 36	292 54	Humboldt	1800	1·262
Caracas	10 31	292 56	Humboldt	1800	1·209
Silla de Curacas	10 31	292 59	Humboldt	1800	1·189
Cumana	10 28	295 51	Humboldt	1800	1·178
Il Impossibile	10 26	295 55	Humboldt	1800	1·219
‡ Cocollar	10 10	296 01	Humboldt	1800	1·178
Caripe	10 10	296 07	Humboldt	1800	1·178
Cumanaçoa	10 16	296 02	Humboldt	1800	1·168
Trinidad	10 39	298 25	Sabine	1822	1·198
At Sea	10 53	299 29	Humboldt	1799	1·220
Port Praya	14 54	336 30	Sabine	1822	1·193
”	”	”	King	1826	1·177
”	”	”	Fitz Roy	1832 1836	1·156

§ 8. *Intensities from* 1·15 *to* 1·05.

Station.	Lat.	Long.	Observer.	Date.	Intensity.
Bonin	27 07	142 24	Lütke	1828	1·111
Oahu	21 18	202 0	Douglas	1830	1·119
Mowi	20 52	203 19	Freycinet	1819	1·133
Owhyhee	19 43	203 50	Douglas	1834	1·098
Galapagos I.	0 15 S.	269 29	Fitz Roy	1835	1·069
Guajaquil	2 13 S.	280 03	Humboldt	1803	1·058
§ Cuenca	2 55 S.	280 47	Humboldt	1802	1·029
Alausi	2 13 S.	281 0	Humboldt	1802	1·058
Riobamba	1 42 S.	281 16	Humboldt	1802	1·077

	Lat.	Long.	Intensity.
* Mean, 3 stations	9° 18′	285° 42′	1·227
† Mean, 8 stations	10 24	292 35	1·203
‡ Mean, 5 stations	10 18	296 00	1·184
§ Mean, 4 stations	2 16 S.	280 46	1·055

	Station.	Lat.	Long.	Observer.	Date.	Intensity.
*	Quito	0° 14′ S.	281° 16′	Humboldt	1802	1·067
*	San Antonio	0 0	281 19	Humboldt	1802	1·087
*	Villa di Ibarra	0 21	281 42	Humboldt	1802	1·028
†	Pasto	1 13	282 39	Humboldt	1801	1·048
†	Almaquer	1 54	283 06	Humboldt	1801	1·067
†	Popoyan	2 38	283 21	Humboldt	1801	1·117
‡	Carthago	4 45	283 54	Humboldt	1801	1·077
‡	Ibague	4 27	284 41	Humboldt	1801	1·147
‡	S. Fé de Bogota	4 36	285 47	Humboldt	1801	1·147
§	Honda	5 12	285 07	Humboldt	1801	1·117
§	Bocca di Nares	6 10	285 20	Humboldt	1801	1·137
‖	Atabapo	4 03	291 50	Humboldt	1800	1·077
‖	Apure	7 53	292 01	Humboldt	1800	1·107
‖	Atures	5 38	292 02	Humboldt	1800	1·117
‖	Carichana	6 34	292 06	Humboldt	1800	1·157
‖	Calabozo	8 56	292 10	Humboldt	1800	1·107
¶	Iavita	2 48	291 59	Humboldt	1800	1·068
¶	St. Carlos	1 54	292 22	Humboldt	1800	1·048
**	Nueva Barcelona	10 07	295 16	Humboldt	1800	1·127
**	St. Thomas	8 08	296 06	Humboldt	1800	1·107
	River Gambia	13 08	343 27	Sabine	1822	1·141
	Sierra Leone	8 29	346 45	Sabine	1822	1.053

§ 9. *Intensities from* 1·05 *to* 0·95.

Station	Lat.	Long.	Observer	Date	Intensity
Manilla	14 36N.	116 18	Lütke	1829	1·044
Guahan	13 26	144 44	Lütke	1829	0·980
Agagna	13 28	144 58	Freycinet	1818	0·968
At Sea	6 55	158 02	Lütke	1827	0·990
At Sea	11 27	161 52	Lütke	1827	0·970
At Sea	2 56	162 50	Lütke	1827	1·018
At Sea	4 17	162 54	Lütke	1827	1·001
At Sea	3 47	162 59	Lütke	1827	1·010
At Sea	18 44	163 55	Lütke	1827	0·989
At Sea	0 35N.	232 56	Lütke	1827	1·013

* Mean, 3 stations	0° 2′	281° 26′	1·061
† Mean, 3 stations	1 52	383 02	1·077
‡ Mean, 3 stations	4 36	284 47	1·124
§ Mean, 2 stations	5 31	285 14	1·127
‖ Mean, 5 stations	6 36	292 02	1·113
¶ Mean, 2 stations	2 21	292 10	1·058
** Mean, 2 stations	9 07	295 41	1·117

Station.	Lat.	Long.	Observer.	Date.	Intensity.
Ayavaca	4° 38′ S.	280° 26′	Humboldt	1802	1·019
Gualtaquillo	4 52 S.	280 26	Humboldt	1802	1·028
Gonzanama	4 13 S.	280 27	Humboldt	1802	1·009
* Guancabamba	5 14 S.	280 37	Humboldt	1802	1·019
Pucara	5 56 S.	280 37	Humboldt	1802	1·009
Amazon's River	5 48 S.	281 13	Humboldt	1802	1·009
Tomependa	5 31 S	281 24	Humboldt	1802	1·019
Montan	6 33 S.	281 10	Humboldt	1802	1·009
† Micuipampa	6 44 S.	281 21	Humboldt	1802	1·000
Santa	8 59 S.	281 23	Humboldt	1802	1·019
Caxamarca	7 09 S.	281 25	Humboldt	1802	1·019
Maranham	2 32 S.	315 39	Sabine	1822	1·016

§ 10. *Intensities below* 0·95.

Station.	Lat.	Long.	Observer.	Date.	Intensity.
St. Thomas	0 25	6 45	Sabine	1822	0·931
St. Catherine	27 26 S.	311 27	King	1827	0·920
Rio de Janeiro	22 55 S.	316 51	Freycinet	1817 1820	0·890
,,	,,	,,	Lütke	1827	0·886
,,	,,	,,	Erman	1830	0·879
,,	,,	,,	Fitz Roy	1832	0·878
Bahia	12 59 S.	321 30	Sabine	1822	0·898
,,	,,	,,	Fitz Roy	1836	0·871
Pernambuco	8 04 S.	325 09	Fitz Roy	1836	0·914
Ascension	7 56 S.	345 36	Sabine	1822	0·920
,,	,,	,,	Fitz Roy	1836	0·873
St. Helena	15 55 S.	354 17	Fitz Roy	1836	0·836

Division II. Southern Hemisphere.

§ 11. *Intensities from* 0·95 *to* 1·05.

Station.	Lat.	Long.	Observer.	Date.	Intensity.
Cape of Good Hope	34 11 S.	18 26	Freycinet	1818	0·945
,,	,,	,,	Fitz Roy	1836	1·014
Rawak	1 34 S.	131 00	Freycinet	1818	1·044
Ulean	7 22 N.	143 57	Lütke	1828	1·004
Lugunor	5 29 N.	153 58	Lütke	1828	0·998
Los Valientes	5 46 N.	157 05	Lütke	1828	0·993

* Mean, 7 stations 5° 10′ S. 280° 43′ 1·017
† Mean, 4 stations 7 21 S. 281 20 1·012

Station.	Lat.	Long.	Observer.	Date.	Intensity.
Ualan	5° 21′ N.	163° 23′	Lütke	1827	1·002
At Sea	4 20 S.	238 13	Lütke	1827	0·998
At Sea	13 09 S.	251 20	Lütke	1827	1·014
Casma	9 38 S.	281 25	Humboldt	1802	1·000
Guarmey	10 04 S.	281 39	Humboldt	1802	1·000
* Huaura	11 03 S.	282 14	Humboldt	1802	1·009
El Ramadal	11 32 S.	282 35	Humboldt	1802	1·009
Lima	12 03 S.	282 53	Humboldt	1802	1·077
Goriti	34 57 S.	305 03	King	1829	1·041

§ 12. *Intensities from* 1·05 *to* 1·15.

Mauritius	20 09 S.	57 31	Freycinet	1818	1·096
„	„	„	Fitz Roy	1836	1·192
Amboyna	3 42 S.	128 08	Rossel	1792	1·097
Otaheite	17 29 S.	210 30	Erman	1830	1·172
„	„	„	Fitz Roy	1835	1·017
Coquimbo	29 59 S.	288 34	Fitz Roy	1835	1·111
Blanco Bay	38 57 S.	298 01	Fitz Roy	1832	1·113
Monte Video	34 53 S.	303 47	King	1830	1·065
„	„	„	Fitz Roy	1833	1·055
At Sea	40 55 S.	307 00	Lütke	1827	1·110

§ 13. *Intensities from* 1·15 *to* 1·25.

Timor	10 10 S.	123 40	Freycinet	1818	1·177
Valdivia	39 53 S.	286 31	Fitz Roy	1835	1·238
Concepcion	36 42 S.	286 50	Lütke	1827	1·234
„	„	„	King	1829	1·250
„	„	„	Fitz Roy	1835	1·186
Valparaiso	33 02 S.	288 19	Lütke	1827	1·170
„	„	„	King	1829 1830	1·176

§ 14. *Intensities from* 1·25 *to* 1·35.

Juan Fernandez	33 38 S.	281 07	King	1830	1·262
At Sea	41 00 S.	282 30	Lütke	1827	1·324
Port Low	43 48 S.	285 58	Fitz Roy	1835	1·326
Chiloe	41 51 S.	286 04	King	1829	1·321
„	„	„	Fitz Roy	1834	1·304
At Sea	49 18 S.	302 48	Lütke	1827	1·268

* Mean, 5 stations 10° 52′ S. 282° 10′ 1·019.

§ 15. *Intensities from* 1·35 *to* 1·45.

Station.	Lat.	Long.	Observer.	Date.	Intensity.
Bay of Seals	25° 43′ S.	113° 20′	Freycinet..........	1818	1·421
R. Santa Cruz	50 07 S.	291 36	Fitz Roy	1834	1·425
Port Desire	47 45 S.	294 05	Fitz Roy	1833	1·355
Sea Bear Bay......	47 51 S.	294 12	King	1829	1·361
At Sea	55 25 S.	298 27	Lütke	1827	1·413
Falkland Ids.......	51 33 S.	301 55	Freycinet..........	1820	1·363
„	51 32 S.	301 53	Fitz Roy	1833	1·349
„	„	„	Fitz Roy	1834	1·385

§ 16. *Intensities from* 1·45 *to* 1·55.

Station.	Lat.	Long.	Observer.	Date.	Intensity.
Port Famine	53 38 S.	289 02	King	1827	1·505
„	„	„	Fitz Roy	1834	1·560
St. Martin's Cove ..	55 51 S.	292 26	King	1827	1·498

§ 17. *Intensities from* 1·55 *to* 1·65.

Station.	Lat.	Long.	Observer.	Date.	Intensity.
New Zealand	35 16 S.	174 00	Fitz Roy	1835	1·591

§ 18. *Intensities from* 1·65 *to* 1·75.

Station.	Lat.	Long.	Observer.	Date.	Intensity.
Sydney	33 51 S.	151 17	Freycinet..........	1819	1·631
„	„	„	Fitz Roy	1836	1·685
King George's Sound	35 02 S.	117 56	Fitz Roy	1836	1·709

§ 19. *Intensities from* 1·75 *to* 1·85.

Station.	Lat.	Long.	Observer.	Date.	Intensity.
Hobart Town......	42 53 S.	147 24	Fitz Roy	1836	1·817

Additional Table, containing the Observations made by M. Erman at sea, on his return from Kamtschatka to Europe by Cape Horn.

These observations were received from M. Erman since this Report was sent to press, which occasions their being given in a separate table.

	Latitude.	Longitude.	Dip.	Intens.
Pacific Ocean	51° 03′	203° 32′	67° 09′·5 N.	1·522
	53 35	213 38	71 05·5	1·587
„	55 33	221 01	75 33·1	1·639
	54 27	221 23	73 40·0	1·673
„	43 18	230 24	66 44·5	1·580
	40 03	233 39	64 00·7	1·551
„	39 12	235 28	63 40·0	1·528
	38 0	235 54	63 41·5	1·556
„	31 51	234 18	56 31·9	1·435
	30 31	235 41	55 05·0	1·394
	29 04	238 24	53 20·8	1·380
„	28 41	238 59	53 05·5	1·402
	28 04	239 08	52 09·5	1·364
„	26 36	239 28	50 22·6	1·377
	26 0	238 54	49 26·1	1·321
	25 21	238 37	48 06·5	1·356
„	23 12	238 15	45 20·5	1·341
	23 0	238 12	44 14·4	1·289
	21 14	237 57	42 17·0	1·271
„	19 39	237 45	40 07·8	1·241
	18 36	237 34	39 03·0	1·219
„	16 56	237 13	35 34·7	1·185
	15 15	236 55	32 28·4	1·183
„	13 37	236 36	29 45·7	1·158
	12 18	236 28	27 09·3	1·143
	11 18	236 22	25 44·4	1·136
„	9 43	235 58	23 06·4	1·107
	8 55	235 57	20 57·7	1·082
„	7 15	236 26	17 51·9	1·053
	6 27	236 42	17 08·8	1·055
	5 49	236 38	15 24·8	1·056
„	4 35	235 47	13 02·6	1·049
	2 42	234 17	9 18·0	1·028
	1 33	233 29	7 21·2	1·018
„	0 46	232 54	5 15·4	0·992
	0 9	232 27	3 30·4	0·986

	Latitude.	Longitude.	Dip.	Intensity.
Pacific Ocean	0° 12′ S.	232° 09′	3° 8′·5	0·997
	0 6 S.	231 44		0·995
	0 7 N.	230 40	3 45·3	1·014
”	0 8 N.	229 44	4 19·3	1·022
	0 0 N.	229 22	3 49·5	1·029
”	0 29 S.	228 41	2 38·3	0·977
	0 40 S.	228 30	2 16·8	0·980
”	0 53 S.	228 16	2 10·9	1·000
	1 7 S.	228 0	1 32·8	1·028
”	1 47 S.	227 18	0 14·6 S.	1·015
	1 52 S.	226 28	0 16·2 N.	0·996
”	1 53 S.	225 32	0 42·6 S.	0·942
	1 52 S.	225 03	0 0·9 N.	1·008
”	1 30 S.	223 46	0 46·7 N.	1·015
	1 37 S.	222 12	0 57·4 N.	1·004
	1 48 S.	221 49	0 3·7 S.	1·009
”	2 11 S.	221 13	0 21·8 S.	1·022
	1 57 S.	221 0		1·001
	2 19 S.	220 16	0 39·4 S.	0·981
”	4 30 S.	218 42	5 3·9 S.	1·016
	5 34 S.	218 3	7 29·8 S.	1·032
”	7 03 S.	217 4	10 07·3 S.	1·031
	7 45 S.	216 53	11 27·1 S.	1·009
	8 06 S.	216 41	12 46·8 S.	1·033
”	9 22 S.	215 58	15 18·5 S.	1·066
	10 22 S.	215 21	17 16·7 S.	1·105
”	11 13 S.	214 59	18 18·0 S.	1·081
	11 54 S.	214 52	19 10·8 S.	1·070
”	12 2 S.	214 51	19 32·9 S.	1·114
	12 56 S.	214 38	21 19·1 S.	1·118
”	13 7 S.	214 37	21 16·9 S.	1·124
	13 44 S.	214 51	22 23·6 S.	1·095
	14 01 S.	214 31	23 28·6 S.	1·075
”	14 55 S.	213 59	24 54·2 S.	1·121
	14 43 S.	212 26	24 23·2 S.	1·091
”	19 06 S.	209 49	31 56·5 S.	1·253
	22 17 S.	209 29	35 51·8 S.	1·209
	24 51 S.	210 0	40 19·4 S.	1·250
”	26 56 S.	209 54	43 05·5 S.	1·349
	27 43 S.	209 57	44 02·9 S.	1·324
	28 48 S.	213 08	45 27·9 S.	1·257
”	29 04 S.	213 25	45 26·5 S.	1·339
	30 33 S.	212 58	47 20·6 S.	1·371

	Latitude.	Longitude.	Dip.	Intensity.
Pacific Ocean......	32° 22′ S.	214° 35′	49° 07′·1 S.	1·361
”	34 23 S.	216 27	51 12·7 S.	1·370
”	34 55 S.	218 29	52 29·3 S.	1·392
” {	34 28 S.	220 19	50 32·9 S.	1·426
	36 17 S.	219 50	52 17·6 S.	1·407
”	37 39 S.	218 4	53 52·4 S.	1·489
”	42 04 S.	218 44	58 48·4 S.	1·509
”	44 24 S.	221 59	61 4·2 S.	1·543
” {	45 6 S.	225 11	61 56·7 S.	1·545
	45 05 S.	228 23	61 43·9 S.	1·611
	47 13 S.	237 34	63 15·5 S.	1·583
” {	48 11 S.	242 23	63 39·6 S.	1·609
	48 50 S.	245 29	64 25·5 S.	1·666
”	51 03 S.	252 22	65 48·6 S.	1·614
”	55 03 S.	266 24	66 16·1 S.	1·630
”	56 28 S.	276 38	65 05·6 S.	1·576
”	56 05 S.	284 36	62 51·3 S.	1·537
”	58 31 S.	289 35	61 05·6 S.	1·522
Atlantic Ocean	57 26 S.	295 56	60 06·5 S.	1·491
” {	56 02 S.	299 34	58 26·6 S.	1·391
	55 36 S.	302 02	57 28·4 S.	1·412
”	52 44 S.	304 26	54 29·0 S.	1·301
”	50 12 S.	304 17	51 09·5 S.	1·280
”	47 11 S.	306 20	48 44·5 S.	1·233
” {	39 48 S.	308 45	40 27·0 S.	1·023
	37 09 S.	309 41	36 41·9 S.	1·016
” {	35 44 S.	310 23	34 09·9 S.	0·938
	33 04 S.	312 02	30 3·4 S.	0·984
”	29 53 S.	312 28	25 32·5 S.	0·923
”	27 58 S.	314 20	22 01·2 S.	0·899
”	26 22 S.	315 30	19 44·7 S.	0·880
” {	24 12 S.	316 19	16 02·0 S.	0·844
	24 24 S.	316 12	15 47·9 S.	0·916
	24 18 S.	318 35	16 35·0 S.	0·867
” {	24 53 S.	324 26	18 29·9 S.	0·852
	24 26 S.	325 12	15 17·1 S.	0·811
	24 06 S.	325 14	15 56·6 S.	0·809
” {	20 56 S.	325 15	9 45·1 S.	0·816
	20 00 S.	325 0	7 53·3 S.	0·743
” {	19 38 S.	324 56	7 34·0 S.	0·792
	18 57 S.	324 57	7 19·8 S.	0·820
” {	17 33 S.	325 54	4 44·0 S.	0·784
	16 17 S.	326 30	2 28·0 S.	0·795
” {	15 56 S.	326 33	1 33·5 S.	0·797
”	14 53 S.	326 49	0 24·8 N.	0·838

	Latitude.	Longitude.	Dip.	Intensity.
Atlantic Ocean	14° 25′ S.	327° 05′	1° 28′·8 N.	0·856
	13 18 S.	327 22	3 18·2	0·812
"	9 42 S.	328 15	9 28·0	0·892
"	5 19 S.	329 12	17 43·0	0·922
"	3 51 S.	329 19	20 24·2	0·949
	1 53 S.	329 33	23 28·9	1·031
"	0 26 N.	329 45	27 16·5	1·043
"	2 30	329 32	30 48·4	1·074
"	4 26	329 56	34 29·5	1·094
"	5 45	331 21	35 16·5	1·094
"	9 36	333 34	39 14·4	1·125
	10 24	333 35	40 48·3	1·114
"	11 3	332 38	41 54·8	1·187
	12 36	331 42	44 4·3	1·209
	14 36	330 58	46 20·9	1·201
"	15 53	329 26	48 15·9	1·273
	16 41	328 48	49 52·0	1·238
"	19 05	326 42	51 59·6	1·311
	21 01	325 07	54 44·0	1·314
"	24 0	322 55	58 17·2	1·375
"	26 26	321 55	60 49·0	1·406
	28 02	321 22	61 53·6	1·404
"	29 34	320 14	63 12·0	1·427
	30 30	319 29	64 17·3	1·478
"	31 11	320 12	64 45·7	1·469
	32 55	319 3	65 21·3	1·468
"	33 45	318 36	66 4·4	1·499
	34 29	318 18	67 26·5	1·500
"	35 0	318 33	67 36·6	1·505
	36 15	319 56	68 17·5	1·507
"	37 26	321 22	68 19·4	1·501
	38 24	322 57	69 07·4	1·491
"	40 09	325 20	69 32·9	1·504
	41 27	327 25	70 03·6	1·466
"	42 29	328 34	69 47·6	1·512
"	44 22	330 55	71 07·1	1·515
"	46 46	335 42	70 18·5	1·463
"	47 47	343 58	69 46·0	1·421
	47 46	344 25	70 14·9	1·419
"	48 13	347 7	69 27·8	1·422
"	49 16	351 58	69 10·5	1·416
British Channel	50 48	358 54	68 45·0	1·380

Section III.—General Conclusions.

In considering the comparative fitness of the three kinds of magnetic lines, those of equal variation, equal dip, and equal intensity, to promote a knowledge of the system of terrestrial magnetism, the lines of equal intensity have in one leading respect an advantage over the other two. Viewed under the most favourable circumstances and in its simplest aspect, the magnetism of the earth is still, it must be acknowledged, a highly complicated subject; and needs not the additional complication of its phænomena being involved with considerations foreign to itself. Now the lines of equal dip and equal variation do not express simple magnetic relations. The lines of equal dip, for example, connect those stations on the earth's surface where the direction of the magnetic attraction forms a certain angle with the horizontal plane at the station. But every station has its own horizontal plane depending on the direction of gravity, which has no known or necessary connexion with magnetism. The zero planes thus differing, the equality of dip does not express, or necessarily imply, a simple magnetic relation, but has reference to the attraction of gravitation as well as to that of magnetism. The lines of equal variation express a complex relation of a similar character. Here also the zero planes change with the station; and, the variation being the same at two stations, by no means implies parallelism in the direction of the needle at them, or any other specific relation whatsoever independent of the geographical pole, which pole has no known or necessary connexion with magnetism. It is not the same with the lines of equal intensity. Whatever may be the sources of magnetic attraction, and wherever their situation in space,—whether superficial as regards the earth,—or above or beneath its surface—the line of equal intensity expresses the equality of their resultant at all those points of the earth's surface through which it is drawn, unmixed with any considerations foreign to magnetism. They are pure magnetical isodynamic lines at the surface of the globe; and express a common relationship to the sources of magnetical attraction. The instruction they convey is therefore more simple, direct and unequivocal than in the case of the other two. The eye of the mathematician may discern the pure magnetic indication through the complex signification of the lines of equal variation and dip; but the lines of intensity are better suited to convey the system of magnetism as indicated by the phænomena to the general apprehension.

I proceed to notice a few of the most striking inferences which are deducible from the observations of intensity recorded in this report.

1. *The lines of equal intensity are not parallel with the lines of equal dip, and the difference is systematic.*

In 1805 M. Biot published an investigation of the laws which should govern the dip and the intensity, in the hypothesis of a magnet situated at the centre of the earth, having its poles infinitely near to each other, and directed to opposite points on the surface of the globe. It is a well-known consequence of this hypothesis, that the lines of equal dip and equal intensity on the earth's surface should everywhere be parallel to each other.

It has always appeared to me that the distinguished author of this investigation has been taken much beyond his meaning, when he has been supposed to have propounded this hypothesis as a general representation of the facts of terrestrial magnetism then known, or of those which should be shown by more extensive experience. He was doubtless fully aware that, many years antecedently, the phænomena of the variation had been shown by Dr. Halley to be wholly irreconcileable with the geometrical deductions from a single central magnetic axis; and that Euler, who may in some degree be regarded as an opponent of Halley upon the subject generally, fully acquiesced in this conclusion. Accordingly, M. Biot made no comparison of the hypothesis with the variation, considering no doubt that its inapplicability in that respect had been already shown. A few facts of the dip were the only observations with which he compared the formulæ of his hypothesis, and with some of these it appeared to accord tolerably; but still there were anomalies which drew from him the acknowledgement, that to represent even those few facts of the dip, it would be necessary to add to the influence of the primary axis the supposition of subordinate centres. That he had no expectation of its proving applicable to the intensity, any more than to the variation, is, I think, beyond a question, when we read the following sentence: "Quant à la declinaison et à l'intensité nous avouons franchement que nous ne savons absolument rien sur leurs lois ni sur leurs causes: et si quelque physicien est assez heureux pour les ramener à un principe unique, qui explique en même temps les variations de l'inclinaison, ce sera sans doute une des plus belles découvertes que l'on ait jamais faites."*

* *Journal de Physique*, vol. lix. p. 450. The state in which the question was left by Halley and Euler was, I believe, as follows: Halley decided in

The light in which I have thus considered M. Biot's essay is the same, I think, in which it was regarded at the time, by his distinguished coadjutors in this and so many other branches of science. MM. Gay Lussac and Humboldt, in closing the account of their magnetic observations on the continent of Europe in 1805 and 1806, remark as follows: "Les inclinaisons correspondantes données par la théorie d'après M. Biot, sont toutes beaucoup plus grandes, car les plus petites différences vont à près de 4°. En supposant la position de l'équateur magnétique, rigoreusement déterminée, il en resulteroit qu'en Europe, il y a une inflexion considérable des parallèles magnétiques vers l'équateur, occasionnée par l'influence de quelque centre particulier. Mais pour tirer aucune conclusion à cet égard, il est prudent d'attendre que des observations exactes et plus nombreuses fournissent *des bases solides, sur lesquelles on puisse élever une théorie rigoreuse qui les embrasse toutes**." It is here fully recognised that M. Biot's was not "cette théorie rigoreuse" which, resting on the solid basis of induction from a competent assemblage of facts, should have a proportionate claim to be regarded as a general representation of the phænomena.

In showing the incompatibility with subsequent observations of this "abstraction mathématique," as M. Biot himself designated it, I do not therefore consider myself as opposing either his opinions or his expectations.

It has sometimes appeared to me that the very simplicity of the laws of this hypothesis has tended to counterbalance in some degree the advantage it produced, in recalling attention to a subject, the interest in which had been for some years suspended. Apart from the question of accordance or non-

favour of four poles, as the best representation of the phænomena: Euler hesitated to accede to this until it should be shown more decisively that the phænomena might not be represented by a single excentric axis, having its semi-axes of unequal length; claiming in such case the preference for the latter supposition over that of four poles, as being more suitable for geometrical deductions. To have accomplished what such men as Halley and Euler had left incomplete would have been an undertaking not unworthy of M. Biot; but it would have required the preliminary labour of collecting together, as M. Hansteen has since done, the great body of the facts of observation, which, at the time his essay was written, were scattered in the journals of travellers and navigators, and in the transactions of learned societies of many countries. This labour might well in prospect have deterred him from the attempt; but it was indispensable for the purpose of furnishing the basis of a philosophical induction of such general laws as should comprehend the whole of the phænomena. On no less solid foundation was it probable that phænomena should be represented, known to wear so complicated an aspect, and which had been the subject of the long-continued investigation of the eminent men above noticed.

* I have put in Italics the part of this extract to which I particularly refer.

accordance with facts, simplicity recommends itself to all; and persons imperfectly acquainted with the phænomena may have been led by it to undervalue *observation*, when detached portions of its facts, inconsistent with the hypothesis, may have come under their notice; and, departing from the principles of inductive philosophy, may have suffered themselves to look to the hypothesis rather than to the phænomena. The simplicity of its resulting phænomena is, however, that characteristic in which it specially departs from the facts of nature. The real phænomena are complex, as all who have studied them will most readily admit; and it can scarcely be expected that the laws which are to represent them should not also have in some degree an appearance of complexity, until the laws of their causation shall be discovered.

In a science which stands in need of national aid for its experimental extension, it is peculiarly desirable to remove such erroneous impressions as militate against a belief in the value, and consequently the importance, of experimental research.

I propose, therefore, in the first place, to show, that the irreconcilability of a single central axis does not rest on insulated facts only, or, as some may have supposed, on the conclusions of a single observer, but that all those who have principally concurred in extending the boundaries of our experimental knowledge of late years, have arrived at the same conclusion in that respect, and have uniformly borne testimony to the inapplicability of the formulæ of that hypothesis to represent their respective observations; and, secondly, to direct the reader's attention to those facts in particular, which may produce the readiest conviction of the systematic departure of the lines of dip and intensity from that law of the hypothesis by which they should have parallel courses.

We have already seen the conclusion at which MM. Gay Lussac and Humboldt arrived in 1807, namely, that their observations in France, Italy, and Germany, taken in conjunction with M. de Humboldt's in America, could only be reconciled with M. Biot's hypothesis, by supposing the existence of a secondary centre extending its influence over the continent of Europe, and acting conjointly with the primary.

From 1807 the spirit of experimental inquiry slumbered for a while; the times were unpropitious to a research which required freedom of access to different countries, and safety and facility in traversing extensive spaces of the earth's surface. At length it revived nearly simultaneously, in Capt. de Freycinet's voyage of circumnavigation, and in the British expeditions for the discovery of a north-west passage. Between 1818 and

1823 I had the good fortune to enjoy opportunities of observing the magnetic phænomena over a portion of the globe amounting to about one-eighth of its surface, or the quarter of an hemisphere. In comparing, on my return to England, the observations of dip with M. Biot's formula, the differences between calculation and experiment were seen to be not at single stations only, but *systematic*, extending over large spaces of the globe; the discrepancies were also so great as (in the words which I employed in 1825) to make it "certain that no two positions could "be assigned to the magnetic poles, which would enable a cal"culation of the dip as a function of the magnetic polar distance, "in which differences from fact should not be found of 10° and "upwards." Further, in comparing the observations of dip and intensity with the parallel course, which, according to the hypothesis, the lines of equal dip and equal intensity should preserve, their irreconcilability with this law was shown to be so great and so systematic as to be "decisive against the sup"posed relation of the force to the observed dip; and equally "so against any other relation whatsoever, in which the re"spective phænomena might be supposed to vary in corre"spondence with each other." Another important difference was also pointed out. In the hypothesis the maxima of dip and intensity are coincident: with this the observations were at variance; those of the intensity placing its maximum several degrees to the southward of the geographical position which the observations of dip indicated as that of the dip of 90 degrees*.

In 1830 M. Erman returned from a journey in which he had carried magnetic observations over a space on the globe still more extensive than mine, and (which should be specially noticed) so entirely distinct from mine, that we had not a single

* The observations of intensity arranged around their own centre presented much less discordance with the laws of an uniaxal hypothesis than appeared in those of the dip when referred to the position of the pole as indicated by the dip of 90 degrees. By substituting in the formula of that hypothesis the "itinerary distance from the maximum of intensity" for the "magnetic polar distance," and employing this formula as an empirical representation, it was found to correspond with the facts of the intensity within the district comprised by my observations, with no very material discrepancies. In that portion of the hemisphere in which the influence of the primary centre is predominant, the variations of the intensity may be easily imagined not to differ greatly from the effect of a single axis; and such is apparently the fact. It happened that my observations, extensive as they were, fell within that limit; had they been pursued a few degrees further to the eastward, the influence of the Siberian centre would have become more sensible, and the uniaxal formula would have ceased to afford even an approximate representation of the facts. But this perhaps will be better understood when the sequel of the report has been read.

station in common. I cannot state his conclusions better than by giving his own words*.

"*Lignes à égale Intensité, ou Lignes Isodynamiques.*—Esperant encore completer mes observations relativement à ces lignes interessantes, pendant mon passage du Brésil en Europe, je me borne ici à en relever quelques particularités frappantes, et nommement celle, qu'en Siberie les lignes isodynamiques ne sont rien moins que parallèles aux lignes d'égale inclinaison. Nous voyons au contraire sous le meridien d'Obdorsk et de Tobolsk, les premières avoir des branches déscendantes presque verticales ou légèrement infléchies du N.O. au S.E., tandis que les lignes à inclinaison égale y sont presque horizontales.

* * * * *

"Ces indications préliminaires suffiront pour prouver que l'ancienne théorie, développée par Euler et Krafft, et plus tard par MM. Humboldt et Biot, et qui ne suppose *qu'un seul axe magnétique*, est absolument en défaut pour les loix de l'intensité de la force magnétique. En effet, l'intensité n'étant d'après cette théorie qu'une fonction de l'inclinaison, les lignes qui representent l'un et l'autre de ces phénomènes, devraient conserver une marche toujours parallèle. On peut en tirer la conséquence interessante, que la position des deux poles magnétiques n'est pas la seule qui règle les phénomènes de l'inclinaison et de la declinaison dans les différentes parties du globe; mais qu'il existe encore une cause secondaire qui n'affectant toutefois que tres faiblement la declinaison et l'inclinaison, et la dernière d'autant moins qu'on l'observe plus près de l'équateur, exerce cependant sur les loix de l'intensité une influence si puissante qu'elle en efface presque tous les caractères déduits par la théorie."

M. Erman's conclusions, in respect to the non-parallelism of the lines of dip and intensity, and the insufficiency of a single magnetic axis to represent his observations, were almost identical with mine. Our difference, in regard to the particular class of the phænomena which were most at variance with that hypothesis, arose from the different parts of the globe which had been the field of our respective researches.

I have next to state the inferences of M. Hansteen as *an experimentalist*, drawn from his observations in his own extensive journeys. This need occupy the less space, because I have already† endeavoured to show, as clearly as the necessity

* *Mémoires de l'Acad. Imp. des Sciences de St. Petersburg*, 1831, (*Bulletin Scientifique*).

† Fifth Report of the British Association, p. 72—73.

of great condensation would admit, the arrangement of the lines of intensity, and their systematic departure from parallelism with those of the dip, which, in his theory of four poles, founded on the assemblage and study of the earlier observations of the dip and variation, M. Hansteen had anticipated, previous to his own experiments. It is sufficient to show, as may be done by a single sentence written since his return from Siberia, that the results of these have accorded with his previous views. "Thus is confirmed in the clearest and most satisfactory manner what I had earlier inferred from the two other magnetic phænomena; namely, that in the northern hemisphere there are two magnetic centres, or poles; and that the westernmost, in North America, has a sensibly greater intensity than the easternmost in Siberia*."

Having thus shown the concurrent opinions which those who have most extensively engaged in the experimental inquiry have been led to form, it remains to place the facts themselves in a convenient manner before the general reader. The complete view of the systematic difference in the course of the two kinds of lines is best obtained, by comparing the map of the intensity lines in this Report with M. Hansteen's map of the dip lines for 1780, in the Fifth Report of the British Association†. The lines of dip have undergone some changes since that period, but none which much affect their general configuration. All readers, however, may not have that volume at hand, and I have therefore traced in Plate I. the course of the line of equal intensity which passes through our own islands, for 160 degrees of longitude, and have exhibited it in comparison with the neighbouring lines of dip. The line of intensity, shown by the continuous line, is taken from the general map accompanying this memoir. The portions of dip-lines, marked by the dotted lines, are taken from M. Erman's map drawn from his own observations, in the *Annalen der Physik*, vol. xxi. The intensity line, which in the meridians of 280° and 290° is in close juxtaposition with

* *Ann. der Physik*, vol. xxviii. p. 579.

† I may take this opportunity of stating that the sea portions of M. Hansteen's map of the dip in 1780 rest on the authority of between 900 and 1000 observations of the dip *made at sea* between the years 1767 and 1788, and that these are tabulated in the Appendix of the *Magn. der Erde*. The observation of the dip at sea in favourable weather was the habitual practice of many of the scientific navigators of that period, such as Le Gentil, La Perouse, Ekeberg, Lewenhorn, and our own countrymen Phipps, Hutchins, Abercrombie, and Pickersgill. It is much to be wished that it were a more frequent practice now. M. Erman, in his voyage from Kamtschatka to Europe, found a number of days sufficiently favourable to enable him to observe the dip in not less than 167 geographical positions at sea.

that of 50° of dip, successively intersects in its eastern progress all the lines of dip between 52° and 73°, with which latter it coincides in lat. 60° and long. 10°; it then again descends, intersecting successively, a second time, the same lines of dip, until it touches that of 57° in long. 70°. When it is seen that the *same* line of intensity successively coincides with the lines of dip of *twenty different degrees*, it must be admitted that their systems are not parallel, and that the conclusion was justly drawn, that the facts could not be represented by an hypothesis in which the intensity should vary as any function of the dip. A conclusion by no means at variance, however, as has been erroneously imagined, with their having a causal connexion.

Nor is the fact of non-parallelism confined to the northern hemisphere; on the contrary, the southern hemisphere exemplifies it in a still more striking degree. Thus we have in South America the line of unity under a dip of 0, as observed by M. de Humboldt in Peru; and at the Cape of Good Hope, the same line of unity under a dip *exceeding* 50°, as shown by the concurrent observations of Captains de Freycinet and Fitz Roy; whilst at Port Desire and at the Falkland Islands, these officers found an intensity of 1·36, with nearly the same dip as had been found at the Cape of Good Hope accompanying an intensity less than unity.

In M. Erman's dip-lines (Plate I.), which represent his own recent observations, and are quite independent of preexisting evidence, we see the same double flexure, of which the importance, in its bearing on physical causes as well as on empirical laws, was pointed out in the Fifth Report of the British Association, page 67. This double flexure takes place also in the intensity lines, but in a more marked degree. In both series of lines the radii vectores drawn from the geographical pole have two maxima and two minima; a line joining the parts of each curve which approach nearest to one another, i.e. at the points of minima, will divide the area into two unequal portions, the larger comprehending the American, and the smaller the Siberian centre of attraction. But there is a distinction in this respect between the two series of curves of dip and intensity, which has been pointed out by M. Erman, and is illustrated by the annexed diagram (Plate II.), taken from his paper in the *Annalen der Physik*, vol. xxi. The diagram represents the northern hemisphere, on which the curves of intensity of 1·45 and of 75° of dip are drawn. The longitudes of the maxima of both these curves are nearly the same; but not so those of the minima. In the curve of dip, the minima

are in the longitude of 35° and 140°; in the curve of intensity in those of 20° and 175°. The Siberian portion of the intensity curve bears consequently a larger proportion to the whole area of that curve, than the Siberian portion of the dip-curve does to its total area. From the general resemblance of the several lines of dip to each other, and of the several lines of intensity to each other,—the characteristics of each being always marked, though gradually softening as they approach the middle regions of the globe,—the features of distinction which are thus strongly marked in the curves compared by M. Erman, must exist also in a greater or less degree in many. Here, then, is another striking and systematic difference in the two species of magnetic lines*.

2. *The lines of intensity in the northern hemisphere systematically indicate the existence of two centres of attraction of unequal force.*

The examination of the graphical representation of these lines in the maps will convey a clearer apprehension of this systematic indication than a lengthened verbal description. The higher the values of the intensity of each isodynamic line, —in other words, the nearer the lines approach the centres of attraction,—the more unequivocal is their testimony. The smaller areas included by the curves in the Siberian quarter mark the less extensive influence and inferior power of the Siberian centre. Looking next at the values of the intensities represented by the lines, we find in the neighbourhood of New York, a portion of a line of 1·8, to which there is no equivalent in Asia. The highest intensity there is 1·76, observed by Lieut Due at Viluisk, which M. Hansteen believes, and with great probability, derived from the configuration of the lines, to be the highest existing in that quarter. It is improbable, moreover, that the greatest intensity in the American quarter should be found so far south as New York; the configuration of the lines, as shown particularly in the north polar map, indicates the maximum to be nearer Hudson's Bay†.

* M. Erman remarks that the difference is of that character which would appear to indicate for the Asiatic centre a less depth beneath the surface than the American.

† Since the above was written, the first number has reached London of the *Observations Météorologiques et Magnétiques faites dans l'étendue de l'Empire de Russie*, which have been confided to the editorship of M. Kupffer. In the introduction we have a formal recognition of the existence of the Siberian pole. "La Russie est aussi la terre classique du magnétisme terrestre. Il y a un pole magnétique dans le nord de la Siberie."

3. *The two centres of magnetic attraction in the northern hemisphere are not at opposite points; in other words, the difference of geographical longitude between them is not* 180°, *measured both ways.*

This is also best evidenced by inspection. Their distances apart are more nearly 200° measured across Greenland and Norway, and 160° across Behring's Strait.

4. *The magnetic intensity is unsymmetrically distributed in the meridians of the northern hemisphere.*

This is a consequence of the two centres being nearer to each other in the one direction than in the other. If we imagine the hemisphere to be divided into two equal sections, by a plane coinciding with the meridians of 100° and 280° (Plate V.), the American division, which we may call the western section, will contain both centres of attraction, and a higher measure of intensity will be seen to be spread over its meridians than in the corresponding latitudes in the eastern section. Thus we find, that in 150 meridians, or in five-sixths of the eastern section, no intensity of so high a value as 1·7 has been found within the range of observation, and probably does not exist; whilst in the western section there is not a single meridian in which a higher intensity than 1·7 is not found. Europe is situated nearly midway between the centres at their widest separation, and we find that throughout Europe (with possibly the exception of its S.W. extremity in Spain), the magnetic intensity is weaker in every latitude than in the same parallels elsewhere in any other part of the hemisphere.

5. *The lines of intensity in the southern hemisphere have a general analogy with those in the northern hemisphere.*

The materials from whence conclusions may be drawn are fewer in the southern than in the northern hemisphere; but aided by our acquaintance with the magnetic system and distribution in the latter, we are enabled to trace the general analogy of the two hemispheres, though the particular conclusions in the case of the southern must necessarily be less determinate and exact than those we have hitherto discussed.

We have already seen that the lines of dip and force depart from parallelism with each other even more in this hemisphere than in the northern. We may also perceive in the portions of the curves, which observations have as yet enabled us to trace, evidence of the same double flexure which in the other hemisphere we have seen to be characteristic of two centres of governing influence. The radii vectores carried from the south

geographical pole would have also two maxima and two minima. The New Holland curves inclose larger areas than the South American, indicating that the centre to which they more especially belong is more powerful than the other. We have another indication of the same fact in the appearance in Van Diemen's Land of an intensity exceeding 1·8, which in the other hemisphere we have seen to characterise distinctively the centre of primary influence. The coincidence in this respect in the two hemispheres is very striking; not only is the highest intensity yet observed in the one, (1·80 at New York,) matched by the nearly identical value of 1·82 at Hobart Town, but the geographical latitudes of the two observations are also nearly identical, New York being in 40° 43′ N. and Hobart Town in 42° 53′ S.; both being unexpectedly low latitudes in which to find such high intensities.

With regard to the geographical positions of the centres in the southern hemisphere, the observations are yet too few and too distant from them to admit of their localities being assigned with any fair degree of approximation; but by comparing the observations in Southern Africa, and on the east coast of South America, with those of the corresponding parallels in the better known hemisphere, we are able to infer with considerable probability, that the southern centres are not only not in opposite points of the hemisphere,—that is to say, distant 180 degrees of longitude from each other, measured both ways,—but that they are nearer to each other in the one direction, and more distant in the other, than is the case with the centres of the northern hemisphere. We have seen that in the meridians of Europe, where the northern centres are widest apart, the lower intensities extend greatly northward, occupying latitudes which in all other parts of the hemisphere possess a higher intensity. In the southern the same thing takes place, but in greater degree. The line of unity, once thought to be the minimum intensity on the globe, is found on either side the Atlantic in south latitudes exceeding 30°; whence we may conclude that in the higher latitudes of the southern Atlantic, a much lower intensity prevails generally than the lowest intensities in the same latitudes in the northern hemisphere; evidencing that the space between the influential centres is wider in that quarter of the southern, than in the corresponding quarter of the northern hemisphere.

The converse of this should be found in the Pacific section. As the southerly inflection of the lines of low intensity in the South Atlantic is the greatest, so should their southerly inflexion in the opposite section of the hemisphere be the least, of the inflections which these lines undergo in either hemi-

sphere. The observations by which this inference might be confirmed are few, but none give a contrary indication. Every observation in the South Pacific section shows that a higher intensity prevails there than in equal latitudes in the North Pacific section; and, as far as the lines can yet be traced from the observations, the inflection in the South Pacific does appear to be the least marked in character, and to extend over the fewest meridians. It is of course the lines of higher intensity which would afford the more decisive evidence, because their characteristics are more marked; but the authorities for these are few in the part of the space between New Zealand and South America, where they could most illustrate the point in question.

In review, we conclude, therefore, that, as far as observations have yet been made in the southern hemisphere, they accord with a system analogous to that in the northern, of two centres, of unequal force, and at unequal distances apart. The observations further render it probable, that the distances between the centres are still more unequal in the southern than in the northern hemisphere. Admitting the small difference of distribution from this cause, there does not appear reason to suppose that there is any general inequality in the magnetic charge of the two hemispheres; on the contrary, there is every appearance that they have the same.

6. *If the globe be divided into an eastern and a western hemisphere by a plane, coinciding with the meridians of* 100° *and* 280°, *the western hemisphere, or that comprising the Americas and the Pacific Ocean, has a much higher magnetic intensity distributed generally over its surface, than the eastern hemisphere, containing Europe and Africa and the adjacent part of the Atlantic Ocean.*

This is a corollary from (4) and (5) rather than a distinct proposition. The four centres being in the western hemisphere a higher intensity will prevail generally in its meridians; and this is accordant with the whole body of observations distributed over the globe (Plate V).

The equality of the magnetic charge in the northern and southern hemispheres and its inequality in the eastern and western, are important features of the magnetic system manifested by the observations of intensity.

7. *The distribution of the intensity in the intertropical regions is accordant with the conclusions already drawn, of two governing centres in each hemisphere.*

As the lines of higher intensity are those which have the

characteristics of the system most strongly marked, I have chiefly employed them, where observations would permit, in describing its general features. The characteristics soften gradually as the distance increases from the governing centres; but even in the intertropical regions the distribution of the intensity and the arrangement of the lines contribute their testimony to the same system. I have nowhere attempted to assign the precise geographical positions of the centres; and in regard to those of the southern hemisphere especially, have expressly stated, that the facts yet acquired would not enable this to be done within fair limits of approximation. Thus much, however, may be safely said in regard to them, that the primary in the southern, and the secondary in the northern, are at the present time not far from the same meridian; and that the primary in the northern, and the secondary in the southern, are similarly situated, except that their difference of longitude is somewhat greater. If we respectively connect the centres, which thus approximate in longitude, by lines on the globe crossing the equator, the lines will mark those localities within the tropics where the influence of the centres should produce a higher intensity than elsewhere in the same latitudes. Thus we should have two maxima in the intertropical regions; and these should not be in opposite meridians, because the centres are unsymmetrical. Such is actually the distribution of the intensity in these regions. The isodynamic lines which represent unity are the weakest which run unbroken round the globe, and appear twice in every meridian; these approach each other in the meridians of 110° and 260°, whilst, intermediately, they recede from each other, and inclose spaces occupied by a still weaker intensity; the largest of these spaces, corresponding to the widest interval between the centres, is of 210 degrees of longitude, and the smallest of 150 degrees. In the middle of the largest, as the point most distant from all the four centres, we should expect to find the weakest intensity existing anywhere at the surface of the globe; and accordingly at St. Helena, which is nearly in that situation, the intensity observed by Captain Fitz Roy, 0·84, is the lowest determination recorded in this report, and is the locality of the weakest intensity yet observed on the globe. Between St. Helena and the lines of unity on either side, we should have a line representing the value of 0·9, a part of which has been extremely well determined by concurrent observations. This line, being comprehended by the lines of unity, is necessarily a closed one. Observations are yet wanting to show whether the intensity descends as low as 0·8 in the

middle of the larger space, or as 0·9 in the smaller space, which has its locality in the Pacific*.

We may also trace in the intertropical regions another consequence of the inequality of force of the primary and secondary centres. Where the lines of unity approach each other in the Pacific, the primary is to the north, the secondary to the south; the latitude in which the lines approach is consequently to the south of the equator. In the Indian Sea the primary is to the south, and the secondary to the north; and here the latitude in which the lines of unity approach each other is to the north of the equator.

Every geographical meridian has a point of minimum intensity; if these points in different meridians were connected by a line, that line would separate the intensities of the northern from those of the southern magnetic hemisphere. It would be in some respects analogous to the line of no dip, but it would not be a line of equal intensity, as it would consist of intensities varying from unity to the lowest on the globe. Such a line traced on the map is found to differ very considerably in geographical position from the line of no dip.

8. *The geographical position of the maximum of intensity in the North American quarter is not the same with that of the maximum of dip, or with that of the point of convergence of the variation lines.*

It will be necessary here to enter into rather more precise geographical positions than we have hitherto done. In regard to the maximum of dip we cannot err widely in taking the latitude and longitude where Capt. James Ross observed the dip of 89° 59′ in 1831, viz. 70° N. and 263° E. That this is also very nearly the spot to which the variation lines converge may be shown abundantly by the observations made in the different polar voyages by sea and land†. It is marked by an asterisk

* Since the above was written Mr. Erman's sea observations have been received; he crossed the space in the Atlantic included by the line of 0·9 some degrees to the west of St. Helena, and, midway between the north and south portions of that line, found the intensity diminished below 0·8. Captain Fitz Roy's observation at St. Helena is consequently no longer the lowest observed on the globe; and it is probable that even a lower intensity than was observed by M. Erman would be found a few degrees to the south of St. Helena, and nearly in the meridian of that island.

† M. Hansteen, who has brought together the observations of dip and variation made in the different polar voyages, finds that the variations observed to the north of the latitude in which the dip is 90° and in the vicinity of that dip, converge to a point a little to the north of that latitude; and conversely, that the variations observed to the south converge to a point south of that latitude; or, more exactly, that the curves of highest dip are ellipses, having their greater axes

in the North Polar map annexed to this report. If the reader will now refer to that map (Plate IV.), he will see that this position will by no means accord with that which the observations point out for the maximum of intensity. We are not, indeed, enabled to assign the position of the latter as nearly as in the case of the dip; but it must clearly be in a much lower latitude. The intensities observed in Baffin's Bay and the Polar Sea have all a much lower value than at New York; and the general configuration of the lines of intensity would rather point to a maximum in the vicinity of the shores of Hudson's Bay.

This remarkable feature of the system was first brought to notice in the account of my magnetic observations published in 1825*. In a point of so much interest, it is natural to inquire whether there is any indication of a similar separation at the principal pole of the opposite hemisphere. Observations as yet do not enable us to assign with sufficient approximation the places of the maxima in that quarter; but we are in possession of a leading fact, which, by its complete analogy with the phænomena at New York, gives strong ground for believing that in the southern hemisphere also the places of the maxima of the two phænomena are distinct. I have already noticed the almost identity of the force at Hobart Town and New York, under nearly equal geographical latitudes; but there is yet another feature which completes the analogy, and bears directly on the point now treated of. At New York we have the highest intensity of the northern hemisphere, 1·80, *with a dip of* 73° 07′; at Hobart Town the highest intensity of the southern hemisphere, 1·82, *with a dip of* 70° 35′. In both hemispheres *the highest intensity united with a comparatively low dip.* Nor in that quarter is Hobart Town a solitary instance of

in a north-west and south-east direction, and that the variation lines converge not to the point of 90° but to points in this axis. Small differences of position, however, have no effect on the reasoning in the text.

* It has been viewed by M. Kupffer as having a direct and important bearing on the very interesting question of the physical nature of the magnetism of the earth. In the *Ann. der Physik,* vol. xv., after describing the course of the isogeothermal lines (or lines of equal temperature of the earth at 25 metres below its surface) between the meridians of 80° west and 60° east of Paris, he has discussed the influence which the facts represented by those lines should have on the magnetic dip and force, in the case of the earth's magnetism being superficial and induced. The differences of surface temperature affecting the intensity but not the dip would cause the isoclinal and isodynamic lines to separate where otherwise they might have been accordant; and would especially separate the places of the maxima, causing the maximum of intensity to be in the lower latitude. M. Kupffer considers the fact of their being thus separated as giving probability to the aforesaid view of the physical nature of the earth's magnetism.

high intensity with comparatively low dip; at King George's Sound and Sydney, in 34° and 35° south latitude, Captain Fitz Roy found intensities of 1·71 and 1·68 with dips of 64° 41′ and 62° 29′.

Should such a separation exist at the secondary centres, it cannot be expected to be of so striking a character. I wish not to anticipate the more able discussion which we may expect on this point from M. Hansteen, whose long and arduous journeys were undertaken expressly to determine with exactness all the phænomena of the Siberian pole. I will confine myself, therefore, to noticing his remark already referred to, that he believes the intensity observed at Viluisk to be the highest intensity existing in Siberia. Should this be so, the highest intensity in that quarter is certainly not in the same locality as the highest dip*.

Our knowledge of the phænomena in the neighbourhood of the secondary centre in the southern hemisphere is not sufficient to throw any light on this question.

With regard to the direction which the lines of higher intensity may be conceived to take around their maxima in the northern hemisphere, we should infer from the observations that the line representing 1·8 must be a closed curve around the North American maximum only; as must also be that of 1·9, supposing such to exist.

The North American portion of the line of 1·7 appears also to be nearly, if not quite, a closed curve. Encompassed on the north, east, and south, by intensities of less value, the western is the only direction open for its connection with the Siberian portion of the same line. The situation of the two branches of the line of 1·7 in the west of America is marked by the observations;—the southernmost crossing the lower waters of the Columbia River,—and the northernmost between Sitka and Melville Island. Whether these branches join and form a closed curve, or whether they communicate with the Asiatic portion of the same line in some such courses as is represented by the dotted line in the polar map, observations do not yet enable us to decide. No intensity of so high a value as 1·7 has yet been observed between Sitka in 224°, and the meridian

* It is much to be desired that the observations in Siberia should be still further completed by a series of determinations along the shores of the polar sea. If the view here taken be correct, these should exhibit higher dips and lower intensities than were observed at Viluisk. From the liberal support which the Russian government gives to the prosecution of magnetic inquiries we may expect that such observations will not be long wanting.

of 138° in Siberia; and it is possible that a navigator sailing from the Pacific through Behring's Strait, and passing the Bay of St. Lawrence where Admiral Lütke observed 1·65, might proceed to the northward having the spaces included by the closed curves of 1·7 on either side of him.

The space inclosed by the curve of 1·8 possesses a very high degree of magnetic interest, and is well deserving of being traversed by observations as frequent and as accurate as those of MM. Hansteen and Erman in Siberia. The greater part of it is in the British dominion, and over a considerable portion at least convenient means of locomotion are to be found. The British Association had but to express the wish that a magnetic survey of the British Islands should be made, and it was at once responded to by some of its own members. The present volume contains the record of the completion of that undertaking; and it may be permitted to one of the contributors to that work to express a hope, that the attention of the Association may now be given to the British possessions abroad. In the extensive territory under British dominion in India, not a single determination has yet, I believe, been made of the magnetic intensity, and but few of either of the other phænomena. From the well-known zeal of the officers of the Indian service, a recommendation in the proper quarter would speedily cover that large portion of the earth's surface with accurate magnetic determinations. But the Canadian quarter is of prominent interest; a correct delineation of the lines of variation, dip, and intensity in the space included by the curve of 1·8, or in even a portion of that space, would have a high value in theoretical respects. The accomplishment of this service is not altogether beyond the compass of individual means, and needs not, like a southern voyage, await the success of an application to Government. It requires only for its proper execution, that it should be the principal object of the person undertaking it, and that he should be provided with adequate instruments. Were the wishes of the Association expressed in regard to Canada, as they were in regard to the British Islands, I have little doubt that they would soon be complied with by members of their own body*.

* The ground which Capt. Back traversed in his journey in search of Capt. Ross in 1833 and 1834 is of great interest as regards the magnetic intensity; and had that officer been furnished with suitable instruments, and had it accorded with his other objects to have made observations in the manner of MM. Hansteen and Erman at every halting-place, his results might have possessed great value.

The vibrations of the dipping-needle, which he employed to measure the in-

9. *The highest intensity already observed is more than twice as great as the lowest.*

The intensities observed at New York and Hobart Town, compared with that at St. Helena, are as 1·81 to 0·84, or as 2·16 to 1.

St. Helena is not the lowest intensity; and the force at New York and Hobart Town cannot be viewed as abso-

tensity, appear to have been subject to a considerable instrumental uncertainty; and the needle lost magnetism during the absence from England to a large amount, but at what time the loss took place is not very obvious from the observations. Under these circumstances I have not felt that I could assign with sufficient confidence the value of the intensity relatively to Europe at any of Capt. Back's American stations. By grouping them, however, and comparing the values of the intensity in different groups, relatively to each other only, and not relatively to Europe, we may considerably lessen the effect of the irregularities above mentioned, and obtain an indication, which, if we could view it as sufficiently clear from instrumental uncertainty, would possess much interest. For example, if we group neighbouring stations as in the subjoined table, and make the intensity at New York the unity of the comparison, we have as follows: viz.

Station.	Date.	Lat. North	Long. West	Time of Vib.	Therm.	Mean Lat.	Mean Long.	Mean Time of Vibr.	Mean Ther.	Intensity.
	1833	° ′	° ′	s.	°	° ′	° ′	s.	°	
New York	Apr.	40 42	74 01	1·2857	69·	40 42	74 01	1·2857	69	1·000
Fort Alexander	Jun.	50 37	96 21	1·2432	70·5					
Cumberland House	July	53 58	102 22	1·2643	59·5	53 20	102 13	1·2681	68	1·027
Isle à la Crosse	July	55 25	107 55	1·2969	73·5					(*a*)
Fort Chipewyan	July	58 42	111 19	1·3000	95·	59 56	112 32	1·2693	80	1·031
Fort Resolution	Aug.	61 10	113 45	1·2387	65·6					(*b*)
Fort Reliance	Oct.	62 46	109 01	1·2750	44·					
	1834									
	May	......	......	1·2844	49·	62 46	109 01	1·2792	40	0·997
	Oct.	......	......	1·2781	28·					
Musk Ox Rapid	July	64 41	108 08	1·2873	64·					
Rock Rapid	July	65 54	98 10	1·2800	87·					
Point Beaufort	July	67 41	95 02	1·2975	72·	66 51	98 19	1·2838	70	1·002
Montreal Island	Aug.	67 47	95 18	1·2885	74·					(*c*)
Point Ogle	Aug.	68 14	94 58	1·2656	53·					

Here we see that the groups (*a*) and (*b*), which have their mean position about 53° N. and 102° W., (258 east), and 60 N., and 112½ W. (247½ east), have a higher intensity than the more northern group (*c*), which has its mean position about 67° N. and 98° W. (262 east). These groups (*a*) and (*b*) have also a higher intensity than that of Fort Reliance to the north, or New York to the south. New York, Fort Reliance, and the northern group (*c*), scarcely differ in the values of their respective intensities. This arrangement is quite conformable with the lines in the polar map.

I have taken Capt. Back's observations from Mr. Christie's paper in the Phil. Trans. for 1836; the times of vibration at the stations in America being those contained in the table page 393. That table shows that the needle was vibrated at

lutely the highest. If we suppose the minimum to reach 0·74, (one of M. Erman's sea observations is 0·743) and the

every station with its face to the face of the instrument, and that at *some* of the stations it was also vibrated in the reverse position. Where this has been done there often appears a considerable difference between the times of vibration at the same place in the two positions, which must be ascribed to instrumental defect. It does not appear to have been of the nature of a constant error in either position of the needle, as sometimes one position gives the highest intensity and sometimes the other. I have taken the twelfth column just as it stands,—that is, the times of vibration in the position which was everywhere observed, as there can be no question of the comparability of those with each other; and I have reduced the times of vibration to an uniform temperature by the coefficient which Mr. Christie found for that needle; but I have introduced no other corrections, either for loss of magnetism or on any other account. I have grouped the results by taking the mean latitude, longitude, and intensity of the neighbouring stations, connected by brackets.

If the intensities are taken from a mean of all the observations at each of the stations, including those in the reversed, as well as in the direct position of the needle, the inferences drawn above are somewhat strengthened, as is shown in the following table:—

Station.	Lat. North.	Long. East.	Time of Vib.	Ther.	Intensity.
New York	40° 42′	285° 59′	1·2857	69°	1·000
Group (*a*)	53 20	257 47	1·2644	69	1·033
Group (*b*)	59 56	247 28	1·2607	80	1·045
Fort Reliance.....	62 46	250 59	1·2758	40	1·002
Group (*c*)	66 51	261 41	1·2857	70	0·999

Mr. Christie, in combining the observations at different stations and in different positions of the needle, has followed a somewhat different course, and has arrived at somewhat different conclusions. With more perfect instruments,—with observations alike complete at all the stations,—and repeated at New York as well as in London, to test the permanency of the needle's magnetism,—there would not have been room for any difference of view. The only result absolutely deducible from the observations, and in which all persons must agree, is the comparability of the intensities at the different stations of the northern group with each other, and with Fort Reliance; as the observations of May and October, 1834, show by their agreement that during that interval the needle underwent no change. The conclusion to be drawn from this portion of the observations, which are as strictly comparable as the imperfection of the instrument permits, is, that in the district which it comprises no consistent alteration takes place in the intensity. If any small alteration does take place, it would require a more delicate instrument than Capt. Back was furnished with to determine it.

It is in these countries that the statical method of Professor Lloyd would be of the greatest advantage. I have already had occasion to speak of the disadvantage to which the method by horizontal vibrations is exposed in countries of very high dip, where every error in the dip is magnified to a high degree in its effect on the intensity deduced; and of the preference due in such cases to the vibrations of a dipping-needle. But it is well known that this latter method, though a trust-worthy, is far from being a delicate test of differences of mag-

maximum 1·85, the proportion would be 2·5 to 1. It seems probable that this is rather under than over the difference existing in the present distribution of the intensity. If the centres change their relative places, by having unequal motions, both the absolute and the relative values of the maximum and minimum must be variable.

This report has already occupied so large a portion of the annual volume, that I feel the propriety of not permitting the inferences of an individual judgment to trespass further on its pages. I have endeavoured, to the best of my power, to place the facts themselves before the reader in such a manner, that, on the one hand, he may have no difficulty in tracing every observation to its original source,—and on the other, that by the assemblage of the results in one view, he may be enabled with the greater facility to draw his own conclusions.

Having in a former report described M. Hansteen's theory of the magnetism of the earth, and given the formulæ for the variation, dip, and intensity deduced from his hypothesis of two excentric axes of unequal force, it may be expected that I should conclude this report by comparing some of the observed intensities with the results computed by the formula. I may therefore add a few words to show that the proper time for a detailed comparison of this kind has not yet arrived, because observation is still in arrear of theory. Until observation has supplied the materials which theory has required for the correct assignment of the elements of calculation, such a comparison could not be otherwise than imperfect.

The geographical positions of the magnetic poles in the *Magnetismus der Erde* were derived from observations made between 1787 and 1800, which were insufficient to furnish them in more than a very general manner. Since that period also, changes, of the nature anticipated by M. Hansteen, appear to have taken place in the positions of the poles; which consequently require to be assigned afresh (as well as more correctly), in order that the results computed by the formula may represent observations of a more recent date. The materials proper for this purpose are observations in the vicinity of the

netic intensity, even with a good instrument, on account of the shortness of the period during which the needle will continue to vibrate, and the consequent necessity of commencing with a large arc of vibration. With an inferior instrument the limits of error are of course much wider still. In high magnetic latitudes the statical method deserves a decided preference over the method of *horizontal* vibrations, inasmuch as a moderate error of the dip will scarcely have an appreciable effect on the intensity; and over that by *verticul* vibrations, inasmuch as it admits of much greater exactness.

magnetic poles themselves. In the northern hemisphere, these are far more ample and exact than at any former period, owing in great measure to the interest excited by the publication of M. Hansteen's theory. But the corresponding observations in the southern hemisphere are yet wanting; and until these are supplied, we cannot advance beyond an anticipation, more or less confident, of the eventual accordance of the hypothesis, when the correct elements of calculation shall have been obtained; and in this view, we may at least say thus much in regard to the general accordance of the hypothesis with the observations of intensity, that if we omit the consideration of the higher latitudes, where the contemporaneous and correct positions of the magnetic poles are most essential, the formula, even with the elements derived from the earlier and less perfect observations, both represents all the leading features of the system, and shows a fair approximation in individual cases.

The method in which this science has progressively advanced is strikingly illustrative of a passage in Mr. Playfair's writings, in which the distinct offices of theory and experiment, and the value of their co-operation in inductive investigation, are well described. "In physical inquiries the work of theory and observation must go hand in hand, and ought to be carried on at the same time, more especially if the matter is very complicated, for then the clew of theory is necessary to direct the observer. Though a man may begin to observe without any hypothesis, he cannot continue long without seeing some general conclusion arise; and to the nascent theory it is his business to attend, because by seeking either to verify or to disprove it, he is led to new experiments and new observations. He is led also to the very experiments and observations that are of the greatest importance; namely, to those *instanciæ crucis* that naturally present themselves for the test of every hypothesis. By the correction of his first opinion a new approximation is made to the truth, and by the repetition of the same process certainty is finally obtained. Thus theory and observation mutually assist one another; and the spirit of system, against which there are so many and so just complaints, appears nevertheless as the animating principle of inductive investigation. The business of sound philosophy is, not to extinguish this spirit, but to restrain and direct its efforts. It is therefore hurtful to the progress of physical science to represent theory and observation as standing opposed to one another."

The earlier observations of terrestrial magnetism were made without reference to theory. As facts accumulated general conclusions arose. Their elaborate examination conducted to

an hypothesis of four magnetic poles; and this, to the suggestion of new experiments to verify or disprove it. In the northern hemisphere the verification is complete, affording signal proof of the value of experiment directed by theory. A similar verification in the southern hemisphere is yet wanting; and the observations necessary for that purpose will also supply those elements of calculation whereby the hypothesis may be fitted for a detailed comparison with facts. This will be the next "step in the advancement of knowledge;"—the next "term of a series that must end whenever the real laws of nature are discovered";—but which, in its progression, fitly prepares the way for their discovery.

I have already adverted to what the influence of the Association may effect, in causing the spaces yet vacant on the map, in the British possessions in India and Canada, to be filled. But beyond all comparison, the most important service of this kind, which this or any other country could render to this branch of science, would be by filling the void still existing in the southern hemisphere, and particularly in the vicinity of those parts of that hemisphere which are of principal magnetic interest. This can only be accomplished by a naval voyage; for which it is natural that other countries should look to England. That the nations that have made exertions in the same cause do look to England for it, cannot be better shown than by the following extract of a letter of M. Hansteen's, which I take the liberty of introducing here, both for this purpose, and because it expresses in so pleasing a manner, the praise that is so justly due to his own country, and which I am sure will be cordially responded to by all who cultivate science in this country, and particularly by those who know the kindly feeling with which Englishmen are ever welcomed in Norway.

"C'est le Storthing (la Chambre des Députés) de la Norvège, qui a donné les frais à l'expédition en Sibérie. On a fait cela dans un tems où on a refusé les dépenses pour un château de résidence pour sa Majesté à Christiania. Dans un tems, où une telle économie a été nécessaire, il est très honorable, qu'une Chambre, composée de toutes les classes du peuple, même d'un grand nombre de paysans, a *unanimement* résolu de donner les frais pour une expédition purement scientifique, dont les résultats n'auront jamais aucune utilité économique pour la patrie, et dont on ne comprenait pas la haute valeure scientifique. Regardé les ressources très-bornés de notre pays, c'est une générosité presque sans exemple.

"Comme la petite Norvège a fourni toutes les observations entre les méridiens de Greenwich et de Ochozk, et entre les

parallèles de 40° et 75° de latitude boreale, il ne me semble pas une demande trop grande ou immodeste à l'Angleterre, si grande, si riche, si puissante, qui a nécessairement un plus grand intérêt dans toutes les sciences combinées avec la navigation, de fournir toute la partie méridionale de la carte. Une telle entreprise doit réfléchir une splendeur à la nation, et payera à la fin les frais par des résultats aussi utiles pour les sciences que pour la navigation. Il ne faut plus dans notre tems laisser l'avancement des sciences au hasard. Par des observations fragmentaires et discontinués on a tâché avec grande peine d'étudier les phénomènes magnétiques de la terre pendant deux ou trois siècles. Par deux ou trois expéditions litéraires, arrangées *exprès pour ce but*, on pourrait en peu d'années avoir une collection plus complète, et d'une plus grande utilité pour la théorie."

The subject has in every way a claim on this country. The existence of four governing centres, and the system of the phænomena in correspondence therewith, was originally a British discovery. The sagacity of our countryman Halley was the first to penetrate through the complexity of the phænomena, and to discern what is now becoming generally recognised. England was also the first country which sent an expedition expressly for magnetic observation, namely, that of Halley in 1698 and 1699. Whilst approving and cordially co-operating in magnetic inquiries of other kinds which have their origin in other countries, it is right that we should feel a peculiar interest in that in which we have ourselves led the way, especially when its object is subordinate to none.

As the research would require to be prosecuted in the high latitudes, a familiarity with the navigation of such latitudes would be important in the person who should undertake this service; and a strong individual interest in the subject itself would be of course a most valuable qualification. I need scarcely say that the country possesses a naval officer in whom these qualifications unite in a remarkable degree with all others that are requisite; and if fitting instruments make fitting times, none surely can be better than the present.

Viewed in itself and in its various relations, the magnetism of the earth cannot be counted less than one of the most important branches of the physical history of the planet we inhabit; and we may feel quite assured, that the completion of our knowledge of its distribution on the surface of the earth, would be regarded by our cotemporaries and by posterity as a fitting enterprise of a maritime people; and a worthy achievement of a nation which has ever sought to rank foremost in every arduous and honourable undertaking.

Report on the various modes of Printing for the use of the Blind. By the Rev. William Taylor, *F.R.S.*

It must be a matter of great satisfaction and pleasure to every one, who is anxious to alleviate the misfortunes of his fellow-creatures, to find that the British Association has been pleased to take into consideration the various modes of printing in tangible characters for the use of the blind; a subject which has long occupied the attention of many individuals, and lately of some public societies, but which has not made much progress till within the last seven years. Now, however, under such powerful influence, it is likely to receive that attention and assistance which will probably bring it to the highest state of perfection which it is capable of*.

The object in view is twofold, 1st, to print such elementary books as may assist in the intellectual education of the blind, and afford them amusement and occupation during the many solitary hours which they must of necessity, especially in after life, be doomed to pass; and 2ndly, to put into their hands the word of God in such a tangible shape, that they may be able, of themselves, to "read, mark, learn, and inwardly digest" that holy book which is able to make them "wise unto salvation."

When the blind are unemployed, they brood over their misfortunes and draw such comparisons between *their* condition and that of their *seeing* brethren, as tend to disturb their peace of mind, and often to make them discontented: what a blessing then will printing in tangible characters prove to that unfortunate class of society, by opening to them new fields of delight, and placing within their reach treasures which otherwise they never could by their own exertions possess!

I am sorry, however, it has not fallen to the lot of one better able to report upon this most interesting and important subject; not that I want zeal in the cause, but on account of the difficulty of acquiring a full and accurate knowledge of what progress it *has* made and *is now making* in various parts of the world. I have not spared to avail myself of such information as I could collect

* The Edinburgh Society of Arts, &c. were the first, as a public body, to take up this subject in this country, and by their great and praiseworthy exertions they have not only collected much valuable information relating to printing for the use of the blind, but have ascertained the opinion of almost every person known to have turned his attention much to the subject, as may be seen by their excellent report published in June last.

from the few sources which are within my reach*; but after all I shall stand in need of indulgence from those who may peruse these pages, as much valuable matter will unavoidably have escaped me, and some errors crept into the statement I have given.

Origin of printing in characters in relief for the Blind.

To enter into a complete history of the first rude attempts to form alphabets and to print raised characters for the use of the blind, would be uselessly to swell this report; I shall, therefore, only briefly notice the earlier inventions, and hasten to the modern improvements, which certainly have the largest claim upon our attention.

So far back as the 16th century letters were cut in wood for the use of the blind; but instead of projecting as they now do, they were sunk or made hollow, on which account the fingers were unable to trace the forms of the letters unless they were of a very large size.

In 1575 Rampazzetto published examples of letters carved in wood, *in relief*; but, as they were not separate, but like the stereotyping of the present day, they were laid aside as inconvenient.

In 1640 moveable characters were cast in lead at Paris by one Peter Moreau, but the expense, or difficulty of the undertaking, prevented his going on with it.

Various other persons, at different times, have made characters and letters for the blind both in wood and metal, but not with much success till the year 1783, when punches were cut and matrices struck, in which characters were cast by Fournier, at the expense of M. Rouillé de l'Etang, Treasurer of the Philanthropic Society in Paris. These characters however, (from an erroneous notion that all objects or models for the use of the blind should be made of great dimensions), were considerably larger than was necessary or convenient; consequently a new set of punches was cut, and letters, nearly similar to those now in use in France, were cast in the foundry at Vaflard. Since that time many of the letters have been improved in their form, and the metal of which they were cast rendered more durable by altering the proportion of the ingredients it contained.

Types for the blind differ from those in ordinary use, in that they are set up and read from left to right, whilst in those for printing with ink the reverse order is observed. Besides this the stem or body of the types used in France is made in the shape of a T, the letter being on the top or cross-piece which prevents

* Chiefly am I indebted to the works of Dr. Guillie, Dr. Klein, Prof. Zeune, &c.

the type falling through the bars of the frame in which it is placed, while the shank or tail goes between them. But this kind of type is very heavy and clumsy, and the lines of printing cannot be brought very near to each other, which tends greatly to increase the bulk as well as the expense of the books.

In 1784 the first European institution for the instruction of the blind was established at Paris by Valentine Haüy; and although many attempts to produce raised characters or letters for their use had previously been made, yet *printing* for the blind may be said to have been unknown till 1785, when M. Haüy submitted to the Royal Academy of Sciences a memorial, in which he explained the "means he proposed to employ for the instruction of the blind." A committee was appointed to examine this plan, who allowed that M. Haüy was the *inventor of printing books in relief for the blind*, and strongly recommended his invention to the approbation of the Academy. Since that time some change and improvement have been made in a few of the letters; for instance, the e is a little less liable to be mistaken for the c or o; the u not so narrow and therefore not so like to the a; the k also is opened to be less like the h, &c. I would here state that the French use both capitals and "lower case," and the form of the letter approaches that of the Latin or Italian.

"In the Paris Institution," says Dr. Guillie, "the blind pupils set and distribute the types and print the books themselves, and some who are expert will arrange about a dozen lines of an 8vo page in a quarter of an hour." Whether or not they have now adopted the common or screw press for printing, I am not able to say, but formerly the types were set in a frame (as before mentioned), the paper well wetted, laid upon them, and over all three or four folds of thick flannel; it was then passed through a large wooden rolling press* and the impression taken out on the other side. In this manner a variety of books have been printed, amongst which are spelling books, grammars, geography, portions of the Scripture, short pieces of poetry, with miscellaneous extracts, &c.†

* The rolling press was used because it was thought that a sufficient pressure could not be given with the common screw press. In the former case only one line at a time is pressed by the roller, and consequently the whole force is sustained by that line, but in the latter the pressure is distributed over the whole page at once, and therefore must be very great to work a 4to or folio. But I believe the perpendicular pressure is now used in France, and was introduced some years ago by M. Clousier, printer to the King.

† In Zürich there is an excellent establishment for the education of the blind, in which they print books in raised letters, &c., and have already several books, such as a grammar, Scripture phrases, &c., which are given to the pupils gratis on leaving the Institution.

The paper used in printing in relief should be very good and strong, not liable to tear, tolerably thick and well-sized. If it be too thick the letter will not be sharp nor well-defined; neither should the impression be too much elevated, or it will increase the bulk of the book and be more liable to injury. About $\frac{1}{40}$ or $\frac{1}{35}$ of an inch is generally found sufficiently high for small type impressions. Alphabets and first books for beginners should be a little higher. "This kind of printing," says Dr. Guillie, "cannot be done on both sides the paper, as in taking off the second page the first would be destroyed*". In this state printing for the blind remained till Mr. Gall of Edinburgh, about the year 1831 or 1832, introduced what he calls a *triangular*, or rather *angular, alphabet*. This is chiefly a modification of the common alphabet, though some of the letters are entirely arbitrary. For instance, the A is a triangle standing upon one of its angles; the B and D are triangles with two small ears or projections at the upper angle; and the P and Q are also triangles, similar to the above, only they have the projections at the lower angle. The O is a square standing upon one of its corners; and the G is the same, only a little smaller, with a perpendicular tail to it about as long as one of the sides of the square. The C is an obtuse angle concave to the right hand. The E the same with an additional line bisecting the angle. The T is a perpendicular line with a very short one crossing it in the middle. The other letters partake in a great degree of the common form, except that the R, S, and W are angular instead of curved†. Mr. Gall conceives that curves are not so easily distinguishable by the touch as angles.

———"besitst die Anstalt einen Apparat, mit welchem eben so schnell, wie in gewöhnlichen Druckereien, Bücher in erhabener Schrift, für Blinde, lesbar gedruct werden. So besitzen wir z. B. ein Sprachbuch für Blinde, 60 Seiten stark; ferner eine systematische Sammlung von Bibelsprüchen, unter dem Titel, Biblisches Sprachbuch für Blinde * * * * * solcher Bücher werden den austretenden Blinden jedesmal unengeltlich mitgegeben."—Orell on the Zürich Institution for the Blind, &c., 1835, page 43.

* An attempt however has since been made (I have been told) at Philadelphia, to print upon both sides by engraving or punching the letters upon pewter plates, and passing two of these plates, through a rolling press, with a very thick paper, almost reduced to a state of pulp, between them, but I believe the plan was too expensive to be employed generally. Mr. Gall of Edinburgh has also printed on both sides the paper by arranging the types so that the lines on one side the leaf just occupy the spaces between the lines on the other. A little room is gained by this method, but as it requires much nicety in laying the paper upon the type to print the second page, lest the first should be injured, some time must be lost in taking off the impressions; which, to me, renders the advantage of such a plan very doubtful.

† Mr. Gall has recently altered the form of some of his letters, and thereby greatly improved them.

About that time several schools or asylums for the blind were established in America. In Philadelphia the Gospel of Saint Mark was published in a raised type and printed on both sides the leaf as before mentioned; the letters are something between the Italic and written characters. I am not aware that much more has been done there; but at Boston printing in raised characters for the blind has been carried to a great state of perfection under the direction and superintendence of that able and zealous friend to the blind, Dr. S. G. Howe. The form of the letter differs a little from the "lower case" used in this country, but the impressions are exceedingly sharp and good. Many books have been published there, and at a very cheap rate, as will appear from the following extracts from Dr. Howe's excellent letter to the British and Foreign Bible Society.

From the "Monthly Extracts from the Correspondence of the British and Foreign Bible Society."

From the Rev. Dr. Howe, Director of the New England Institution for the Education of the Blind.

"Boston, U.S., Nov. 20, 1836.

"I now forward you a box containing two complete copies of the New Testament of our Lord and Saviour in raised characters, one bound in 4 vols. the other copy in 2 vols. For adults and persons who would use them carefully the copy in 2 vols. would be best; for children the one in 4 vols.

"You ask, what would be the cost of a hundred or a thousand copies of the New Testament? I answer that they may be printed and bound for 1*l.* 10*s.* But you will observe that the paper on which the copies I send you are printed is very tough and peculiar in its fabric; it was made for the purpose, and is saturated with animal size, so that it will be very durable. If you depress one of the letters you will observe the paper will spring back again, which I fear will not be the case with the kind of printing you sent to me. The cost of our Testament was little over 2*l.* sterling, another edition might be had cheaper. I rejoice to learn that an interest is beginning to be felt on the subject of printing for the blind, for it has been the object nearest my heart for the last four years."

After urging the desirableness of using the *common* letter, Dr. H. proceeds:

"I have known of several cases where blind persons had learned to read at home: we had one boy enter our institution who knew how to read and spell in our first books, though he was but seven years old and was born blind. His mother, a small farmer's wife, had procured a book a year before and taught him.

Again, there are many persons who lose their sight *after having learned the common form of letters*; and they have little difficulty in recognising them by the touch, but would be discouraged by a new character*."

The Doctor, after stating some cases of bedridden persons, and persons of *weak* sight though not blind, reading the raised type with their fingers, goes on to say: "We have about fifty in this institution who are of the age for instruction, and forty of them can read; twenty can read very fast, and will run through a chapter of the Testament in just the time it takes a seeing person to read twice the quantity, observing all the stops. Some of our children at the age of six can read.

"* * * * * The elevation of the letters, the hardness and durability of the impression, the strength of the paper, the method of binding, all these are to be considered, experimented upon, and greatly improved. It is a wide and interesting field, and right glad am I that labourers have entered into it in England; and I wish only that they may *work with one common plan.* I believe much more printing has been done for the blind in this Institution than in all England * * * having obtained the sanction of the American and Massachusetts Bible Societies, the American Tract Society, &c. I have printed an abridgement of Murray's Grammar, a Spelling Book, a Hymn Book, The Dairyman's Daughter, Baxter's Call, The Pilgrim's Progress, Child's First Book, second ditto, and last, not least, the entire New Testament!

"I have now in the press a Geography, and shall continue as long as I have health and the means to operate with.

"With regard to any funds to be applied by your Society, I would earnestly recommend, and in the name of the blind implore, that they may be upon works which have not yet been printed for them, or which they cannot obtain for a long time. *Their books must be few* and the same work should not be printed in different places, but different books, so that exchanges may be made; for instance, if you could send us fifty copies of the Psalms or * * *, we could send you fifty of the Acts or the Evangelists * * *. We should like very much to print an edition of the Psalms of David, say five hundred copies, for the use of the blind of England and of this country: the expense would probably be from 225*l.* to 250*l.* if done up in the best and most durable style†. Perhaps it would be more extensively useful to print them on our medium type, that is a size between the large type

* This is much against the use of arbitrary alphabets.

† The Committee have voted 150*l.* and are to receive fifty or a hundred copies.

on the *title* page of the Testament and the small type of the same.

"If the British and Foreign Bible Society would undertake to appropriate funds for this purpose, and present to the blind of England and this country an edition of the Psalms, it would confer happiness and a blessing upon many.

"P.S. November 24. Our Geography is finished, and our press is now throwing off an edition of 'The Sixpenny Glass of Wine,' printed at the expense of the American Sunday School Union.

"I hope your Society will allow us to send you the Psalms; it would make one snug volume and be finished in four weeks."

In April 1832 the committee of the Society for the Encouragement of the useful Arts in Scotland, presented their report upon a method of printing for the blind invented by Mr. Hay of Edinburgh, and in consequence of their recommendation the Society, in the following year, offered their gold medal, value 20*l.*, "for the best communication on a method of printing for the use of the blind." The authors of the communications were required to "investigate what *form* and *size* of the letters or characters, and what *number* of those should be adopted, with a view to constructing a general alphabet for the blind in Great Britain and Ireland; and secondly, the best and cheapest methods of printing such letters or characters in relief, so as to render them most easily and accurately distinguishable by the touch."

In consequence of this notice, communications with printed and written specimens of alphabets, types, &c. were received by the Society.

For Competition. From Mr. Alexander Hay of Edinburgh; Mr. J. P. Walker, Glasgow; Miss M. Banks, Edinburgh; Mr. Mungo Ponton, Edinburgh; Mr. John Henderson, Edinburgh; Mr. John Richardson, Edinburgh; Rev. Edw. Craig, Edinburgh; Mr. James Gall, Edinburgh; Dr. Edmund Fry, London; Mr. Richard Eaton, Coventry; Mr. D. Macpherson, Edinburgh; Mr. John Lothian, Edinburgh; Mr. Robert Milne, Edinburgh; Mr. John Johnstone, Glasgow; Mr. J. Jones, Bishop Wearmouth.

Not for Competition. From Lady C. Erskine, Edinburgh, two letters on the subject, but no alphabet; Mr. D. Vallance, Lanarkshire, method of teaching the blind to read; Dr. R. K. Greville, Edinburgh, alphabet; J. Simpson, Esq., advocate, Edinburgh, alphabet.

A Committee was appointed by the Society to consider and report upon these several communications.—Now as "twelve of

these proposed alphabets were composed entirely of arbitrary symbols, while three were merely modifications of the ordinary Roman and Italic characters, the first question that presented itself for their consideration" was *whether some modification of the ordinary Roman or Italic alphabets in common use, or an entirely new arbitrary character, would be best adapted for the use of the blind generally throughout the kingdom*? This was a question of considerable difficulty, especially at that time, when so few experiments had been made upon the subject. The Committee however, in their Report of 1832, gave their opinion in favour of an *arbitrary* character. Since that time Mr. Gall published a little work, which seemed to show that his alphabet* was more legible by the touch and possessed greater advantages than any of the others. This increased the difficulty the Society had to contend with, and induced them to take the opinion of various persons experienced in the education of the blind. Consequently the whole of the communications were sent to various persons, and (among others) to me, in the spring of 1835. Most of these communications were exceedingly clever and interesting†. I read them with very close attention, and examined minutely the various specimens; and in July following returned them to Edinburgh, with a report stating what seemed to me the advantages and disadvantages of each. This report the Society soon after published, together with extracts from other reports, as well as from the communications and fac-similes of the various alphabets, and sent copies to the different institutions, &c.——

Some years ago Mr. Lucas of Bristol contrived an alphabet chiefly from short-hand characters, and in his books uses numerous contractions or abbreviations, and thereby reduces the bulk of the book very much, but increases the difficulty of making out the words, &c.‡ On the 12th of February 1836 a public meet-

* Mr Gall's alphabet was composed of characters in some degree similar to the Roman, or that generally used in printing; but he excluded all curves and circles, and formed his letters entirely of angles and straight lines.

† Many of these communications show great ingenuity and deep research in their authors, and contain so much valuable matter relating to the *general* education of the blind, that a publication of the whole or greatest part of them would be productive of much good to those for whose benefit they were written. But as this would be rather expensive (many of the communications being very long) and as the Edinburgh Society of Arts has already done so much on this subject, it is scarcely reasonable to expect that body to encounter so costly an undertaking, unless they could, from some other source, be assisted in the furtherance of their praiseworthy exertions.

‡ Mr. Lucas uses a new system of spelling, employing only as many letters as are sufficient to give the sound of the word; thus, "adu for adieu," "ni for nigh," "bote for bought," &c. He also uses one letter for several words, as "n

ing was held in Bristol, when a Society was formed, and denominated "*the* Bristol *Society for embossing and circulating the authorized Version of the Bible for the use of the Blind.*" Patron, the Lord Bishop of that Diocese; President, Lieutenant-Gen. Orde.

Amongst other things it was then and there resolved, 1st. "That the system of embossed characters invented by Mr. Lucas for teaching the blind to read, is recommended by its simplicity, and has been proved to be efficacious by several public examinations of his pupils." 2nd. "That a portion of the Holy Scriptures be printed on this system of embossed characters as soon as sufficient funds shall be collected to meet the expenses of publication." 3rd. "That as it is the object of this meeting to enable the blind to read the Holy Scriptures, the support of the Bible Society, the Society for Promoting Christian Knowledge, and other Religious Societies be solicited in behalf of this Society."

When I attended the meeting of the British Association last year at Bristol, I had the pleasure of seeing Mr. Lucas, and witnessing two of his pupils, in the presence of several other gentlemen, read portions of the Scriptures printed in his characters. But the mere reading from a book well known to the pupil, in whatsoever character it might be printed, proves very little, for blind children will generally learn with great ease almost any alphabet set before them; therefore it is necessary to compare the progress made with *different* alphabets, and to consider the *sum of the advantages* possessed by each before it can be determined which is the best*.

At that meeting I had the honour of being introduced to Dr. Carpenter of that city, a gentleman who has evidently thought much and long on this subject, and whose opinion and observations therefore cannot fail to be highly valuable. Dr. C. in his able letter to W. Fraser, Esq., Secretary to the Edinburgh Society of Arts, says, "I should, as Mr. Lucas does, employ

for into, under, &c." "x for example, exercise, &c." (see Explanation of his system of printing for the blind.)

The numerous inconveniences arising from such a plan (unless adopted by everybody, the *seeing* as well as the *blind*) are too obvious to need pointing out, and of too much consequence not to be strictly guarded against. Mr. Lucas has published the Gospel of St. John, and, notwithstanding all his numerous contractions and abbreviations, it is very little less than the same printed by Mr. Alston in Dr. Fry's type.

* Caution is necessary in making experiments on different alphabets. The pupil may be interrupted in reading by holding his finger upon the word under it at that instant; and if upon asking him to name it, it was found that he had pronounced words, in a part of the sentence at which his finger had not yet arrived, this would show that he was reading from memory!

the leading letters beginning words of frequent occurrence, for the words themselves, as *wh.* for *which*; *gl.* for *glory*; *pl.* for *pleasure*, &c." This certainly would tend to lessen the bulk of the book, but I think would not facilitate the reading; for if words, printed in full, can be made out by the first two letters, the remaining ones need not be felt, but the finger passed on to the next word. Besides, as so many of our words begin with the same two or three letters, the *length* of the word, when printed in full, would, at once, without feeling every single letter, show, if a *long* word beginning with *pl*, that it was not *plan*, *plea*, *play*, or any other *short* word, &c. and if *short*, that it was not *plausible*, *plurality*, *plenipotentiary*, &c. It will therefore be highly dangerous to make *much* use, if any, of abbreviations.

Feeling convinced that the letters recommended by Dr. Fry were the only ones likely to be generally adopted, I ventured, in the beginning of 1836, to procure a quantity of type, cast from his punches, by Messrs. Thoroughgood and Co., London, and commenced printing for the use of the children in the Yorkshire school for the blind, and the experiment was most satisfactory. About the same time I found that Mr. Alston (treasurer to the Asylum for the Blind at Glasgow), a gentleman whose zeal and exertions in behalf of the blind must rank him among the best friends of that portion of society, had begun to use types of the same kind, only of a size between the two which I used. Soon after many specimens were printed by Mr. Alston, and amongst others the Book of Ruth, the Epistle of St. James, and the four Gospels, &c.

A few months ago the Society of Arts in Scotland awarded their prize of a gold medal in favour of Dr. Fry's alphabet, but recommended the type to be *fretted* or roughened on the top to give the letters a dotted appearance, and, as they think, to render them more easily legible by the touch; but of this I shall speak hereafter. They also recommend printing upon both sides of the paper.

A few years ago Mr. Gall published the Gospel of St. John in his angular alphabet at 21*s*., and now the *whole New Testament* in Dr. Fry's alphabet is offered for about 32*s*. by Mr. Alston, and I believe for less by Mr. Gall in his angular type. Such is the state at present of printing in raised *characters* for the use of the blind, at least as far as regards "*letter-press*."

Mathematics.

In mathematics very little has been done for the blind in the way of *books*, but various methods have been contrived for teach-

ing common arithmetic and algebra, some of which are very simple and effective*. However, I shall not enter into a description of them here, as they can scarcely be said to form a part of the subject of this report.

Some embossed mathematical diagrams have been printed both in Germany and America, and I believe in France; and in the year 1828 I published the diagrams of the first book of Euclid in an embossed form; but the expense of the copper plates, engraving, &c. deterred me from going on with the work. At Boston, U.S., figures explanatory of mechanics, astronomy, &c., and some very beautiful maps of large size, have been printed; also some chronological tables, &c. Globes and maps have long been made at Paris, and I believe in Germany, by gluing threads upon the lines, or pasting a second map over them; but this cannot properly be called *printing*†.

Music.

Music has been much cultivated by the blind in general, and several *palpable* modes have been invented to facilitate their acquiring a knowledge of it. The French contrived a very ingenious plan, which has been followed in other places. It is a board, with raised lines and pierced full of holes, in which are placed pegs of various shapes to represent the different notes. The same kind of board is now used in the Yorkshire school, but upon a very much smaller scale, having crooked pins for the notes instead of clumsy wooden pegs, and saw-cuts across the board in which to set bits of tin to represent the *bars*. For this improvement we are chiefly indebted to a blind gentleman of York‡. I am informed that music has been printed from moveable types in Germany, France and America, but I have seen only a small specimen from the last-mentioned country. In the

* By help of one of the best of these my own private pupils (blind) have soon acquired a sufficient knowledge of the elements of algebra to enable them to solve quadratic equations with ease and readiness; and one has gone still further.

The pleasure they generally derive from working problems of this kind is very great.

Geometry also, when taught them in a way suited to their peculiar circumstances, seldom fails to afford them great delight, but it must always be made interesting to them or they soon despair of learning it.

† Since writing this I have received from Dr. Howe a copy of a book of plates, or "Diagrams illustrating a compendium of Natural Philosophy for the use of the Blind. Printed at the New England Institution for the Education of the Blind, 1836."

The diagrams seem to be taken from blocks of wood engraved after the manner of copper. The work is admirably got up, and is a very valuable addition to the books for the blind.

‡ W. D. Littledale, Esq.

beginning of this year I published a selection of Psalm tunes, in an embossed form, printed from engraved pewter plates, using the common form of notes, cliffs, time, &c., which are thus rendered familiar to the blind, and enable them more easily to become teachers of music to those who see. Thus I have given an abstract of what I have been able to collect on this subject; but as I have not had an opportunity of visiting many of the institutions abroad, it is probable that much has been done, in the various branches here noticed, which *has* never yet come under my observation, and of which I am totally ignorant.

A comparison between the advantages and disadvantages of the common Roman and arbitrary Alphabets.

The great question "whether it is better to employ the common Roman letters or an arbitrary alphabet in printing for the blind," has long engaged the attention of many who feel an interest in this subject, and numerous and ingenious arguments have been advanced on both sides.

It has been contended that an arbitrary alphabet may be composed of such characters as to possess *greater characteristic difference, be more legible by the touch, and occupy less room, and therefore be altogether better for the blind than that in common use.* This may be *possible,* but such an alphabet I have never seen. There are two things to be considered in forming a *new* alphabet before the shape of the letter or character be determined upon, viz. *whether it is better to have the usual number of characters, or to use a few and to give to each a variety of positions to make up the difference.*

It has also been contended by those who advocate arbitrary characters, that giving a variety of positions to one character reduces the *number of forms,* and must therefore be less burdensome to the memory. But as every *new position* does *in effect* become a new *form,* or something new to be remembered, the difference cannot be very great. Some persons hold that *angular* characters are more legible by the touch than such as are formed partly or altogether of curves; and the contrary has been held by others.

The Edinburgh Society of Arts have recommended (as before stated) the *fretted* types, as being more easy to make out by the touch; but I tried four of the children in the York school with specimens of Mr. Gall's characters both fretted and plain, and they all said they liked the plain best as they could read it with greater facility. The same was the result of Mr. Alston's experiments at Glasgow, as communicated to me in a letter from him*.

* Mr. Alston has lately greatly improved the paper on which he prints, and has also had some improvements made in a few of his letters.

Abbreviations and contractions have been strongly recommended; but if there is too much left to the imagination of the reader, wrong impressions will be often formed, and false ideas acquired; and if a blind person has first to encounter a difficulty, and afterwards to be left in doubt whether he is right or not, he will very soon be discouraged, and lose all interest in that which otherwise would afford him not only occupation and amusement, but also delight and permanent advantage. Those who advocate the use of the common alphabet contend that it has not been *proved* to be less legible by the touch, or to require more space than others of the same sized letters or type, but evidently possesses many advantages over an arbitrary one; amongst others, "it associates" (as Mr. Craig, one of the competitors for the Edinburgh medal, says) "the blind in their literary pursuits more closely with other men, and secures to them from all quarters an aid which they might not otherwise readily attain." With spelling and other elementary books printed in the common character, they can attend with great benefit any school with other children, and *with* them learn their lessons, and *from* them obtain the aid for which one scholar is usually indebted to another. Moreover they may be taught at home by their parents, long before they are old enough to be trusted amongst a number of frolicksome *seeing* companions. These and many other advantages are incompatible with an arbitrary alphabet. In favour of the alphabet in common use it may be stated, that it has been employed by the French, the Americans, Germans, &c., though varying a little in some particulars from ours. The books printed at Boston are without capitals, but the French use both capitals and small letters, so also do the Germans, but they employ the Italian characters. Klein (Director of the Institution for the Blind at Vienna, in his most excellent book *Lehrbuch zum Unterrichte der Blinden*, page 65) says, "Die Form der lateinischen Buchstaben ist am leichtesten durchs Gefühl zu lesen, daher wähle man diese Schrift zum Lesen und Schreiben für Blinde. Einige Buchstaben müssen auch in dieser Schrift noch mehr vereinfacht werden, sowie auch alle unwesentliche, bloss zur Verzierung dienende Züga und Striche wegbleiben müssen.*" Thus it seems from so many nations adopting an alphabet well known among them, that the general opinion is *decidedly against an arbitrary character*.

Klein in his preface to the above book allows it to be possible

* *Translation.* The form of the Latin or Italian letters is the easiest to read by the touch, on which account they are to be chosen in which to print and write for the blind. But some of these letters, even, must be simplified and *deprived of all useless ornaments, &c.*

that characters may be contrived more simple, and in some respects easier to read by the touch, yet he considers the common alphabet the best; and in teaching the blind employs the usual mode of instructing *seeing* children as far as possible; for as long as the blind must live and mix with those who see, it is most desirable to connect the two together both in their education and pursuits; for by so doing that unfortunate class will be spared many a painful reflection on their condition, and escape the bitterness of an unfavourable comparison with their more fortunate brethren*. Besides blind persons may with a pencil or tracing paper write letters to their friends, and their friends may write to them by means of a stile or other blunt point, placing the paper upon something soft so that the letters may be raised on the other side; but this advantage, gratifying in the highest degree to the blind when they are able to practise it, would be greatly diminished, if not altogether destroyed, by the use of an arbitrary alphabet; for then no one could correspond with them who had not learnt their system.

Furthermore, the blind often become scientific men or poets, and probably from the improved methods of conveying instructions to them, this may in future more frequently happen. How delightful then to correspond with others or to record their own thoughts by means of an alphabet *generally* understood! Mr. Alston, in one of his communications to me, states the great delight his pupils enjoyed (who had learnt the common alphabet) in going into the churchyards and reading the grave-stones, &c.

Arbitrary alphabets are more liable to errors of the press than the common, and less likely to be detected on account of their not being so familiar to the printer, &c., so that the blind are thereby exposed to the danger of being misled, and of acquiring erroneous notions, which in many cases might be of serious consequence.

Assuming the reasons in favour of using the common alphabet to be satisfactory, it would appear that the *Roman Capitals*,

* "Daher habe ich getrachtet, so weit es nur möglich war, die gewöhnlichen Unterrichts- und Hülfs-mittel wie man sie für sehende Kinder gebrauchet, auch für die Blinden beyzubehalten, um diesen desto leichter Lehrer zu verschaffen, die sich durch neue Lehrmittel, in welche sie sich selbst erst einstudieren müssen, vielleicht hätten abschrecken lassen. *Dieses bestimmte meine Wahl für die* GEWÖHNLICHEN BUCHSTABEN, obgleich nicht zu läugnen ist, dass die von Hrn *Wolke* und von andern vorgeschlagenen einfachen, der Telegrafen-Schrift ähnliche zeichen zur fühlbaren Schrift leichter sind. So lang der Blinde mit und unter Sehenden lebt, muss man suchen, *ihn in seinem eigenen Benehmen und in der Behandlung, so viel es nur möglich ist, den Sehenden näher zu bringen,* um ihm manchem Anstoss und manche schmerzhafte Erinnerung an seinem Zustand zu ersparen."

as recommended by the late Dr. Fry, and now employed by Mr. Alston, offer the greatest advantages*. Being all of one height they form a regular line in the page, so that there is no danger of the finger of the blind reader straying into the line either above or below; an evil, which in many of the arbitrary alphabets would frequently occur, and which raises a very formidable objection to them †. For if blind persons get puzzled or be led into error by reading, they will have no confidence in what they do, and will therefore never feel any pleasure or interest in reading, but take it up as a school boy does his task. This among other things renders it necessary to be very cautious, lest in attempting to reduce too much the bulk of the books for the blind it be carried so far as to frustrate the object, by making a book difficult to be read, and therefore useless to ninety-nine out of a hundred of those for whose benefit it was intended.

It may not be amiss to observe that when an alphabet or specimen of printing is submitted to the blind in any institution for experiment, a few of the *cleverest* children, whose touch is delicate and acute, are selected to make the trial, and because *these* can easily make out what is submitted to them the experiment is thought to have been *fairly* made. Whereas the greatest proportion of blind persons will always be found amongst those who have to earn their living by manual labour, which blunts their touch and renders them incapable of reading a small-sized letter.

Besides, as the literature for the blind can never be very extensive, the grand aim should be to print chiefly such books as are most necessary; for example, the New Testament, parts of the Old, Catechisms, Hymns, Moral Tales, Spelling Books, Easy Lessons, Fables, &c., and in a type *sufficiently large to be easily read by the average, at least, of the blind.* A "*large* book" surely cannot be a "greater evil" than one *too small to be read,* and therefore *useless.* The Gospels printed upon the plan of White's Diatessaron would probably be a valuable addition to the books for the blind, as the substance of the four Evangelists would then be comprised in the smallest room possible.

At present there is great excitement on this subject and much

* As the small letter or "lower case" is in use among the *seeing,* it perhaps would be well to have a few books printed with that type for the blind; but if the letters are some to go above and some below the lines, as in the b, d, g, y, &c., the bulk of the book must necessarily be a little increased, as the lines must not come so near each other that the tops in one line may interfere with the tails of those in the line above.

† Besides, if capitals to begin proper names, &c. be used (which in my opinion would be of essential service,) the same form of letter will serve if made a little larger.

praiseworthy zeal in operation to further it; and, as opinions vary, many books are printed, in different alphabets or characters, for the use of the blind, each author contending that his plan must be the best. But this contention will soon cease, as some one system will be shown, by the preference of the blind themselves, to be decidedly superior, and all the others will be laid aside; for the blind will, when left to their own choice, use only that which they can read with the greatest facility and satisfaction.

From what is here stated it seems that the alphabet best adapted for the use of the blind is not that which possesses superiority in some one particular, but that which is superior as a *whole*—that which offers the greatest *sum of advantages*. Now, probably, this may not be the one which occupies the least space, for the bulk of the book is of much less importance than the ease with which its contents can be perused. Furthermore, as the object is GENERAL *communication*, the alphabet in common use must afford advantages which are incompatible with an arbitrary one; for should a blind person become deaf, the only means of communicating with him would be by printing in raised letters, or by writing with the finger upon his head, back, &c.; and in such a case how limited would be his intercourse with others, if he had only learnt an arbitrary alphabet, compared with what it would have been had he been taught the one in common use! In the former case only very few could understand him, or be understood by him; while in the latter almost every one could communicate to him some intelligence of what was going on around him, and thereby contribute in no small degree to alleviate the weight of his misfortune, and enliven the dreary gloom which must perpetually hang over his existence.

Account of the discussions of Observations of the Tides which have been obtained by means of the grant of money which was placed at the disposal of the Author for that purpose at the last Meeting of the Association. By J. W. LUBBOCK, *Esq., F.R.S.*

AT the last meeting of the Association held at Bristol I had the honour to communicate the results which I had then obtained; I now wish to explain the manner in which the last grant of money which was placed at my disposal by the Association has been employed.

1. I have engaged Mr. Jones to discuss 13,391 observations of the tides made in this place during nineteen years by Mr. Hutchinson, with reference to a previous transit, or that which precedes the time of high water by about 48 hours. These observations are in the possession of the Lyceum at Liverpool, and they were granted with great kindness by the Committee of that Institution for the purpose of this inquiry.

2. I have engaged Mr. Russell to extend the former discussion of the London Dock observations, by employing all the observations made from the 1st of September, 1801, to the 31st August, 1836, or 24,592 observations. Tables have been formed in precisely the same manner as those already submitted to the Section at the meeting at Bristol. In some instances* irregularities have, in consequence of the additional number of observations, been eliminated, but altogether the agreement with the averages of nineteen years only (13,370 observations) is much closer than I had anticipated.

3. I have also engaged Mr. Russell to examine carefully the *establishment* and average height of high water, in order to ascertain the fluctuations to which these quantities are subject.

Mr. Russell and Mr. Jones have spared no pains in order to render the final results as accurate as the nature of the subject would permit, and I consider myself particularly fortunate in having been able to procure their assistance in these most laborious calculations †.

Even minute discrepancies between the results afforded by the Liverpool and London observations become interesting and

* See the calendar month inequality in the interval for January, the moon's parallax inequality in the height for parallax 56′, &c.

† The author placed before the Section the MS. books containing the details of the work.

deserve elucidation, particularly that in the parallax inequality for the interval to which I shall now briefly advert.

Whatever may be the law of the moon's parallax inequality, we may certainly conclude that it is proportional to the difference of the parallax from 57′ (or to δ P); hence all the averages employed to afford the inequality for H.P. 56′, 57′, 58′, &c., may be combined according to a method which I explained, *Phil. Trans.*, 1836, p. 225. Mr. Russell has in this manner combined all the results afforded by the 13,391 Liverpool observations, and also those afforded by the 24,592 London observations, so as to produce for each place the inequality in the interval and height for H. P. 54′. Hence the Liverpool quantities which are given in the following table may be considered as the average of more than 1000 observations, and the London quantities as the average of more than 2000 observations.

TABLE showing the moon's parallax inequality in the interval and in the height for H.P. 54′, as deduced from theory and observation at London and Liverpool *.

Moon's Transit A.	Interval.			Height.		
	Theory.	Observation.		Theory.	Observation.	
		Liverpool	London.		Liverpool	London.
h m	m	m	m	ft.	ft.	ft.
0 0	....	....	− 3·9	....	....	−0·95
0 30	− 1·0	− 0·4	....	−1·16	−1·23	....
1 0	....	....	− 4·6	....	....	−1·09
1 30	− 3·0	− 2·6	....	−1·14	−1·17	....
2 0	....	....	− 7·8	....	....	−1·07
2 30	− 5·3	− 6·1	....	−1·11	−1·11	....
3 0	....	....	−12·9	....	....	−1·32
3 30	− 7·4	− 7·0	....	−1·09	−1·18	....
4 0	....	....	−15·6	....	....	−1·35
4 30	− 8·3	− 7·7	....	−1·10	−1·21	....
5 0	....	....	−15·0	....	....	−1·67
5 30	− 4·0	− 4·6	....	−1·15	−1·44	....
6 0	....	....	− 8·1	....	....	−1·60
6 30	+ 4·0	+ 3·4	....	−1·15	−1·35	....
7 0	....	....	− 1·1	....	....	−1·38
7 30	+ 8·3	+ 7·5	....	−1·10	−1·21	....
8 0	....	....	+ 1·3	....	....	−1·14
8 30	+ 7·4	+ 7·0	....	−1·09	−1·13	....
9 0	....	....	+ 1·6	....	....	−1·04
9 30	+ 5·3	+ 5·6	....	−1·11	−1·07	....
10 0	....	....	+ 0·3	....	....	−1·02
10 30	+ 3·0	+ 2·4	....	−1·14	−1·17	....
11 0	....	....	− 1·3	....	....	−0·93
11 30	+ 1·0	+ 1·1	....	−1·16	−1·22	....

* I have given a table similar to this in the *Companion to the British Almanac* for 1838; but the argument of that table is the moon's transit B.

In the above columns headed "Observation" the irregularities have been destroyed in the manner explained by me in the Bakerian Lecture, *Phil. Trans.*, 1836, p. 225. The quantities headed "London" have been reduced to transit A by means of certain tables also given in that paper, to which I shall again have occasion to allude. The London height inequality has been multiplied by 1·758. The quantities headed "Theory" were calculated by the Liverpool constants,

$$\log (A) = 9{\cdot}56965, \qquad \log (E) = 0{\cdot}87130.$$

The height is represented by the expression

$$D + (E) \{(A) \cos (2 \psi - 2 \phi) + \cos 2 \psi\},$$

in which ϕ denotes the moon's R. A. — sun's R. A. ψ denotes the sidereal time — the moon's R. A.

I conceive that the best if not the only method of investigating alterations in the height of the land above the water in any given locality where the water is influenced by the tides, will be to examine carefully whether any alteration has taken place in the values of the constants D and (E) for that place, the height of high water being of course always reckoned from some fixed mark in the land.

The nature of the discrepancies between the London and Liverpool results is better exhibited in the following diagrams, where the quantities in the preceding tables have been laid down. The London interval curve, although agreeing in form with the Liverpool interval curve, differs from it throughout by several minutes. This difference seems to be very remarkable. The height curves agree closely, showing that the height inequality varies as the quantity E, as I have supposed. Laplace says "Elles [les marées] augmentent et diminuent avec le diamètre et le parallaxe lunaire, mais dans un plus grand rapport;" but the diagram in the preceding page appears to confirm the truth of this passage only at neap tides.

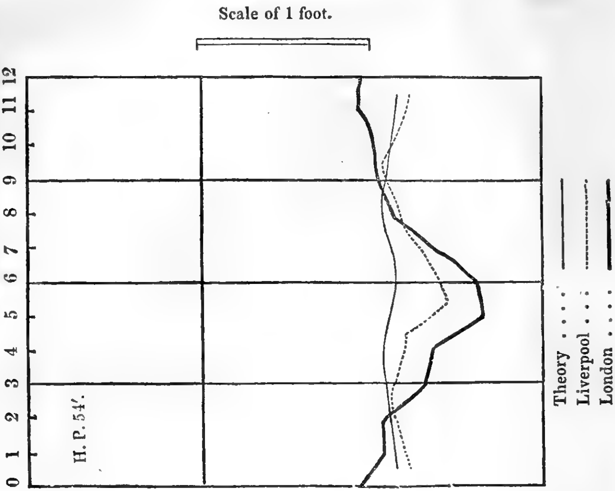


Fig. 2.
Height.

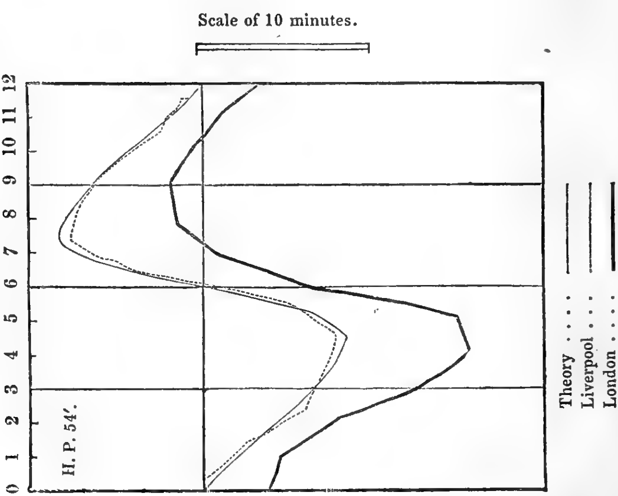


Fig. 1.
Interval.

The inequalities due to the declination of both luminaries are so mixed up together that it is impossible to treat them in the same manner.

The succeeding transits of the moon being denoted by the letters A, B, C, D, E, F; and F being the time of the moon's transit which immediately precedes the time of high water at London, the discussion of the 24,592 London observations has been made with reference to transit B. I intended the transit B also to be used by Mr. Jones in the discussion of the Liverpool observations, but when the work was much advanced I found that Mr. Jones had employed the transit A. However, the tables which I gave in a former paper (Bakerian Lecture, 1836) offer the means of easily transferring the argument from one transit to another. It appears from these tables that the interval between successive transits may be considered constant with reference to the *age of the moon* or time of transit, and depending only upon the parallax and declination. Hence the following table is sufficient.

TABLE showing the interval between the moon's transit and the next succeeding, with a given moon's parallax and declination.

Moon's Parallax.

54′	55′	56′	57′	58′	59′	60′	61′
m 22·6	m 23·2	m 24·1	m 25·1	m 26·1	m 27·1	m 28·0	m 29·0

Moon's Declination.

0°	3°	6°	9°	12°	15°	18°	21°	24°	27°
m 23·2	m 23·3	m 23·5	m 23·8	m 24·3	m 24·9	m 25·6	m 26·3	m 27·1	m 27·9

By means of this table Mr. Russell transferred the quantities furnished by the London calendar month inequality from transit B to transit A, so as to become immediately comparable with Mr. Jones's Liverpool quantities.

Table showing a comparison between the calendar month inequality in the interval as deduced from theory, and from observations at London and Liverpool.

Apparent time of moon's transit A.	January.			February.			March.			Apparent time of moon's transit A.
	Theory.	Liverpool.	London.	Theory.	Liverpool.	London.	Theory.	Liverpool.	London.	
h m	m	m	m	m	m	m	m	m	m	h m
0 0	....	....	−2·3	....	....	−2·7	....	....	−0·8	0 0
0 30	−0·2	−2·4	....	0·0	+0·9	....	−0·1	+0·3	....	0 30
1 0	....	....	−1·7	....	....	−1·8	....	....	−1·6	1 0
1 30	+0·5	−0·2	....	+0·2	+0·5	....	−0·6	+1·1	....	1 30
2 0	....	....	+0·3	....	....	0·0	....	....	−1·7	2 0
2 30	+1·9	+0·9	....	+0·4	+2·9	....	−1·9	+1·1	....	2 30
3 0	....	....	+2·9	....	....	−0·4	....	....	−4·2	3 0
3 30	+3·3	+1·8	....	0·0	+1·0	....	−4·5	−0·9	....	3 30
4 0	....	....	+3·5	....	....	−0·2	....	....	−4·8	4 0
4 30	+3·4	+3·1	....	−1·7	+2·3	....	−7·2	−2·1	....	4 30
5 0	....	....	+3·0	....	....	−2·3	....	....	−5·6	5 0
5 30	+1·3	+0·9	....	−1·9	+1·2	....	−3·9	−2·0	....	5 30
6 0	....	....	−1·6	....	....	+1·5	....	....	+1·9	6 0
6 30	−0·5	−2·1	....	+2·8	+2·8	....	+4·2	+2·7	....	6 30
7 0	....	....	0·0	....	....	+4·6	....	....	+8·2	7 0
7 30	+0·7	+1·1	....	+6·3	+3·6	....	+7·9	+4·0	....	7 30
8 0	....	....	+1·0	....	....	+5·2	....	....	+6·0	8 0
8 30	+2·1	+1·8	....	+6·4	+3·0	....	+6·1	+2·6	....	8 30
9 0	....	....	+1·8	....	....	+1·5	....	....	+0·3	9 0
9 30	+2·4	+2·0	....	+4·2	+1·5	....	+2·5	−0·5	....	9 30
10 0	....	....	+0·1	....	....	−1·1	....	....	−2·8	10 0
10 30	+1·3	−0·2	....	+1·7	−0·9	....	+0·9	−0·7	....	10 30
11 0	....	....	−3·0	....	....	−3·0	....	....	−1·0	11 0
11 30	+0·5	+0·1	....	+0·3	−0·6	....	+0·1	−0·3	....	11 30
	April.			May.			June.			
0 0	....	....	+0·8	....	....	+0·2	....	....	−0·7	0 0
0 30	0·0	+0·3	....	+0·1	0·0	....	+0·3	−1·7	....	0 30
1 0	....	....	+0·6	....	....	+1·2	....	....	+0·8	1 0
1 30	−0·8	+0·2	....	−0·2	−0·9	....	+1·0	−0·8	....	1 30
2 0	....	....	−1·3	....	....	−1·0	....	....	+1·5	2 0
2 30	−2·8	−1·5	....	−0·7	−0·5	....	+2·5	−0·1	....	2 30
3 0	....	....	−3·6	....	....	−2·4	....	....	+2·0	3 0
3 30	−4·6	−3·3	....	−0·4	−2·5	....	+5·5	+1·4	....	3 30
4 0	....	....	−5·2	....	....	−0·2	....	....	+6·4	4 0
4 30	−5·8	−2·7	....	+0·7	−1·6	....	+7·7	+3·9	....	4 30
5 0	....	....	−1·3	....	....	+2·1	....	....	+7·1	5 0
5 30	−2·4	−0·9	....	+1·6	+0·4	....	+4·1	+2·0	....	5 30
6 0	....	....	+1·5	....	....	+1·2	....	....	−0·4	6 0
6 30	+1·7	−1·1	....	−2·1	−1·5	....	−4·1	−2·6	....	6 30
7 0	....	....	+2·0	....	....	−4·2	....	....	−5·9	7 0
7 30	+1·5	0·0	....	−5·7	−4·0	....	−8·5	−4·2	....	7 30
8 0	....	....	0·0	....	....	−4·9	....	....	−6·7	8 0
8 30	−0·5	−1·0	....	−5·8	−4·4	....	−6·7	−2·4	....	8 30
9 0	....	....	−1·8	....	....	−2·5	....	....	−2·9	9 0
9 30	−1·2	−1·3	....	−4·0	−2·1	....	−3·6	−0·3	....	9 30
10 0	....	....	−0·9	....	....	−0·7	....	....	−2·1	10 0
10 30	−0·8	−1·9	....	−1·9	−1·9	....	−1·5	+0·2	....	10 30
11 0	....	....	−2·1	....	....	+0·6	....	....	−0·4	11 0
11 30	−0·2	0·0	....	−0·3	+0·4	....	−0·3	+0·4	....	11 30

Table—continued.

Apparent time of moon's transit A.	July. Theory.	July. Liverpool.	July. London.	August. Theory.	August. Liverpool.	August. London.	September. Theory.	September. Liverpool.	September. London.	Apparent time of moon's transit A.
h m	m	m	m	m	m	m	m	m	m	h m
0 0	....	....	−0·1	....	....	+2·2	....	....	+2·2	0 0
0 30	+0·4	+1·0	....	+0·3	+1·7	....	+0·1	+1·1	....	0 30
1 0	....	....	+1·2	....	....	+1·3	....	....	+1·8	1 0
1 30	+1·9	+1·2	....	+1·4	+2·1	....	+0·1	+1·4	....	1 30
2 0	....	....	+3·2	....	....	+4·0	....	....	+1·4	2 0
2 30	+4·5	+1·3	....	+2·3	+2·2	....	−0·6	+1·0	....	2 30
3 0	....	....	+6·3	....	....	+3·7	....	....	+1·2	3 0
3 30	+7·3	+5·0	....	+2·9	+3·2	....	−3·0	−0·6	....	3 30
4 0	....	....	+8·1	....	....	+4·5	....	....	−4·1	4 0
4 30	+7·7	+5·5	....	+2·1	+1·7	....	−5·0	−2·1	....	4 30
5 0	....	....	+8·3	....	....	+3·6	....	....	−5·2	5 0
5 30	+3·4	+3·1	....	−0·2	+0·6	....	−3·0	−2·5	....	5 30
6 0	....	....	+3·6	....	....	+3·5	....	....	+4·1	6 0
6 30	−2·7	−0·5	....	+1·3	+1·9	....	+3·3	+1·6	....	6 30
7 0	....	....	−1·4	....	....	+4·5	....	....	+8·5	7 0
7 30	−4·1	−0·6	....	+4·1	+3·1	....	+6·3	+3·1	....	7 30
8 0	....	....	+0·1	....	....	+6·2	....	....	+7·0	8 0
8 30	−1·9	+0·7	....	+3·6	+3·8	....	+4·6	+2·3	....	8 30
9 0	....	....	+1·5	....	....	+4·6	....	....	+4·2	9 0
9 30	−0·8	+2·9	....	+2·2	+2·3	....	+1·8	+0·8	....	9 30
10 0	....	....	+1·8	....	....	+2·3	....	....	+4·4	10 0
10 30	−0·3	−0·7	....	+0·5	−0·1	....	+0·3	−1·1	....	10 30
11 0	....	....	−0·3	....	....	+4·3	....	....	+2·8	11 0
11 30	−0·1	+1·2	....	0·0	−0·2	....	−0·1	−0·2	....	11 30

	October. Theory.	October. Liverpool.	October. London.	November. Theory.	November. Liverpool.	November. London.	December. Theory.	December. Liverpool.	December. London.	
0 0	....	....	+2·4	....	....	+0·4	....	....	−1·6	0 0
0 30	−0·2	+0·1	....	−0·3	−0·4	....	−1·0	−0·4	....	0 30
1 0	....	....	+1·7	....	....	−1·4	....	....	−2·6	1 0
1 30	−1·3	−0·9	....	−1·4	−1·1	....	−0·5	−2·1	....	1 30
2 0	....	....	−0·9	....	....	−2·6	....	....	−2·9	2 0
2 30	−3·6	−3·3	....	−2·7	−2·5	....	+0·1	−1·6	....	2 30
3 0	....	....	−3·6	....	....	−2·6	....	....	+0·8	3 0
3 30	−6·3	−3·0	....	−3·2	−3·1	....	+1·5	+1·0	....	3 30
4 0	....	....	−8·5	....	....	−3·8	....	....	+2·1	4 0
4 30	−7·6	−3·7	....	−2·4	−3·5	....	+3·4	+1·4	....	4 30
5 0	....	....	−8·4	....	....	−2·6	....	....	0·0	5 0
5 30	−3·3	−3·4	....	−0·1	−1·0	....	+1·9	+1·0	....	5 30
6 0	....	....	−3·2	....	....	−3·4	....	....	−4·1	6 0
6 30	+2·6	−0·2	....	−0·6	−0·6	....	−2·0	−2·3	....	6 30
7 0	....	....	+2·7	....	....	−6·1	....	....	−8·2	7 0
7 30	+3·8	+1·7	....	−2·6	−4·0	....	−4·3	−3·7	....	7 30
8 0	....	....	+1·9	....	....	−5·0	....	....	−8·0	8 0
8 30	+1·5	−0·2	....	−3·0	−3·0	....	−3·1	−2·7	....	8 30
9 0	....	....	+0·3	....	....	−4·9	....	....	−2·7	9 0
9 30	+0·2	−0·7	....	−2·2	−4·6	....	−1·2	−0·6	....	9 30
10 0	....	....	+1·1	....	....	−1·7	....	....	−1·6	10 0
10 30	−0·1	−1·8	....	−0·7	−1·5	....	+0·1	−0·0	....	10 30
11 0	....	....	+2·0	....	....	−0·1	....	....	−0·4	11 0
11 30	0·0	−0·5	....	−0·3	−0·1	....	+0·3	−0·5	....	11 30

In the *Philosophical Transactions*, 1837, Part I., we have transferred the London quantities to transit A by merely shifting them to the left half an hour, which suffices approximately. Upon comparing in this manner the diurnal inequality at Liverpool and London, I find that it is extremely different; for if we examine the high water *caused by the same tide* at Liverpool and London, we find that if a and b denote two successive heights of high water at Liverpool, and a', b' successive heights at London, if $a > b$, then generally $a' < b'$. I do not think that this circumstance was known previously, although Mr. Whewell, in his examination of the Coast-guard observations, noticed an anomaly of which the origin is similar.

It is remarkable that while at Liverpool the diurnal inequality in the interval is almost inappreciable, at London it is well defined.

The results seem to prove that semidiurnal inequalities in the height are proportional to the quantity E, as might be expected from theory. See *Phil. Trans.*, 1836, p. 223.

If X, Y, Z denote the forces acting in the direction of the coordinate axes upon the fluid particle of which the rectangular coordinates are x, y, z, and if

$$u = \frac{d\,x}{d\,t}, \qquad v = \frac{d\,y}{d\,t}, \qquad w = \frac{d\,z}{d\,t},$$

$$u_{\prime} = \frac{d\,u}{d\,t} + u\frac{d\,u}{d\,x} + v\frac{d\,u}{d\,y} + w\frac{d\,u}{d\,z}$$

$$v' = \frac{d\,v}{d\,t} + u\frac{d\,v}{d\,x} + v\frac{d\,v}{d\,y} + w\frac{d\,v}{d\,z}$$

$$w' = \frac{d\,w}{d\,t} + u\frac{d\,w}{d\,x} + v\frac{d\,w}{d\,y} + w\frac{d\,w}{d\,z},$$

then the differential equation to the surface of the fluid is

$$(\mathrm{X} - u')\,d\,x + (\mathrm{Y} - v')\,d\,y + (\mathrm{Z} - w')\,d\,z = 0.$$

See *Traité de Mécanique*, by M. Poisson, vol. ii. p. 669.

If Q is a certain function of x, y, z, the coordinates of the fluid molecule, and of x', y', z', the coordinates of the centre of the distant luminary,

$$d\,\mathrm{Q} = \frac{d\,\mathrm{Q}}{d\,x}d\,x + \frac{d\,\mathrm{Q}}{d\,x'}d\,x' + \frac{d\,\mathrm{Q}}{d\,y}d\,y + \frac{d\,\mathrm{Q}}{d\,y}d\,y' + \frac{d\,\mathrm{Q}}{d\,z}d\,z + \frac{d\,\mathrm{Q}}{d\,z'}d\,z'$$

$$= \mathrm{X}\;d\,x + \mathrm{Y}\;d\,y + \mathrm{Z}\;d\,z + \frac{d\,\mathrm{Q}}{d\,x'}d\,x' + \frac{d\,\mathrm{Q}}{d\,y'}d\,y' + \frac{d\,\mathrm{Q}}{d\,z'}d\,z'.$$

The equation to the fluid surface is therefore

$$\mathrm{d}\,Q - \frac{\mathrm{d}\,Q}{\mathrm{d}\,x'}\mathrm{d}\,x' - u'\,\mathrm{d}\,x - \frac{\mathrm{d}\,Q}{\mathrm{d}\,y'}\mathrm{d}\,y' - v'\,\mathrm{d}\,y - \frac{\mathrm{d}\,Q}{\mathrm{d}\,z'}\mathrm{d}\,z' - w'\,\mathrm{d}\,z = 0.$$

Bernoulli's theory of the tides, or as it has been aptly termed by Mr. Whewell the *equilibrium theory*, rests upon the assumption that the equation to the fluid surface is

$$\mathrm{d}\,Q = 0, \qquad \text{or } Q = \text{constant},$$

that is, it requires that the quantity

$$\frac{\mathrm{d}\,Q}{\mathrm{d}\,x'}\mathrm{d}\,x' + u'\,\mathrm{d}\,x + \frac{\mathrm{d}\,Q}{\mathrm{d}\,y'}\mathrm{d}\,y' + v'\,\mathrm{d}\,y + \frac{\mathrm{d}\,Q}{\mathrm{d}\,z'}\mathrm{d}\,z' + w'\,\mathrm{d}\,z \quad . \quad . \quad (\text{A.})$$

may be neglected. It seems desirable that some attempt should be made to investigate the nature of this quantity, in order to show *à priori* that the quantity

$$u'\,\mathrm{d}\,x + v'\,\mathrm{d}\,y + w'\,\mathrm{d}\,z$$

may be disregarded. Having *given* the general equation to the surface of the fluid, to find when the distance from the centre of the earth is a maximum (or the time of high water) is not a difficult geometrical problem. In Bernoulli's theory, when the expression for the height is differentiated, in order to solve this question in the usual way various quantities are treated as constants which are not so strictly; and in order to obtain a rigorous solution, it would be necessary to substitute in the expression for the height before differentiation, expressions for the longitude, latitude, and distance of the luminary in terms of the time or mean longitude.

The general equations of the motion of fluids referred to rectangular coordinates are given by M. Poisson, *Traité de Mécanique*, vol. ii. p. 669, and in other works.

$$\frac{1}{\varrho}\,\frac{dp}{dx} = X - \frac{\mathrm{d}\,u}{\mathrm{d}\,t} - u\,\frac{\mathrm{d}\,u}{\mathrm{d}\,x} - v\,\frac{\mathrm{d}\,u}{\mathrm{d}\,y} - w\,\frac{\mathrm{d}\,u}{\mathrm{d}\,z} \quad . \quad . \quad . \quad . \quad . \quad . \quad (\text{A.})$$

$$\frac{1}{\varrho}\,\frac{dp}{dy} = Y - \frac{\mathrm{d}\,v}{\mathrm{d}\,t} - u\,\frac{\mathrm{d}\,v}{\mathrm{d}\,x} - v\,\frac{\mathrm{d}\,v}{\mathrm{d}\,y} - w\,\frac{\mathrm{d}\,v}{\mathrm{d}\,z} \quad . \quad . \quad . \quad . \quad . \quad . \quad (\text{B.})$$

$$\frac{1}{\varrho}\,\frac{dp}{dz} = Z - \frac{\mathrm{d}\,w}{\mathrm{d}\,t} - u\,\frac{\mathrm{d}\,w}{\mathrm{d}\,x} - v\,\frac{\mathrm{d}\,w}{\mathrm{d}\,y} - w\,\frac{\mathrm{d}\,w}{\mathrm{d}\,z} \quad . \quad . \quad . \quad . \quad . \quad . \quad (\text{C.})$$

$$\frac{\mathrm{d}\,\varrho}{\mathrm{d}\,t} + \frac{\mathrm{d}\,.\,\rho\,u}{\mathrm{d}\,x} + \frac{\mathrm{d}\,.\,\varrho\,v}{\mathrm{d}\,y} + \frac{\mathrm{d}\,.\,\varrho\,w}{\mathrm{d}\,z} = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (\text{D.})$$

Let $x = r \cos \phi \cos \mu \qquad y = r \cos \phi \sin \mu \qquad z = r \sin \phi$.

In the problem of the tides ϕ may represent geographical latitude, and μ the sidereal time at the place. If

$$r' = \frac{d\, r}{d\, t} \qquad \phi' = \frac{d\, \phi}{d\, t} \qquad \mu' = \frac{d\, \mu}{d\, t}$$

$$X = \frac{d\, \Omega}{d\, x} \qquad Y = \frac{d\, \Omega}{d\, y} \qquad Z = \frac{d\, \Omega}{d\, z}.$$

The general equations of motion referred to polar coordinates are

$$\frac{d\, p}{\varrho\, d\, r} = \frac{d\, \Omega}{d\, r} - \frac{d\, r'}{d\, t} + \frac{r\, d\, \phi^2}{d\, t^2} - r \cos^2 \phi \frac{d\, \mu^2}{d\, t^2}$$

$$\frac{d\, p}{\varrho\, d\, \phi} = \frac{d\, \Omega}{d\, \phi} - \frac{r^2\, d\, \phi'}{d\, t} - 2\, r \frac{d\, r}{d\, t} \frac{d\, \phi}{d\, t} - r^2 \sin \phi \cos \phi \frac{d\, \mu^2}{d\, t^2}$$

$$\frac{d\, p}{\varrho\, d\, \mu} = \frac{d\, \Omega}{d\, \mu} - r^2 \cos^2 \phi \frac{d\, \mu'}{d\, t} - 2\, r \cos^2 \phi \frac{d\, r}{d\, t} \frac{d\, \mu}{d\, t}$$

$$- 2\, r^2 \sin \phi \cos \phi \frac{d\, \phi}{d\, t} \frac{d\, \mu}{d\, t}.$$

If $\mu = n\, t + \theta$,

$$\frac{d\, \mu}{d\, t} = n + \theta' = n + \frac{d\, \theta}{d\, t};$$

and if we neglect the quantities of the second order

$$\frac{d\, \phi}{d\, t} \frac{d\, \theta}{d\, t}, \quad \frac{d\, \phi^2}{d\, t^2}, \text{ \&c.}$$

$$\frac{d\, p}{\varrho\, d\, r} = \frac{d\, \Omega}{d\, r} - \frac{d\, r'}{d\, t} - n^2\, r \cos^2 \phi - 2\, n\, r^2 \cos^2 \phi \frac{d\, \theta}{d\, t}$$

$$\frac{d\, p}{\rho\, d\, \phi} = \frac{d\, \Omega}{d\, \phi} - r^2 \frac{d\, \phi'}{d\, t} - n^2\, r^2 \sin \phi \cos \phi - 2\, n\, r^2 \sin \phi \cos \phi \frac{d\, \theta}{d\, t}$$

$$\frac{d\, p}{\varrho\, d\, \mu} = \frac{d\, \Omega}{d\, \mu} - r^2 \cos^2 \phi \frac{d\, \theta'}{d\, t} - 2\, n\, r \cos^2 \phi \frac{d\, r}{d\, t}$$

$$- 2\, n\, r^2 \sin \phi \cos \phi \frac{d\, \phi}{d\, t},$$

and the equation to the surface will be

$$\left\{ \frac{d\, \Omega}{d\, r} - \frac{d\, r'}{d\, t} - n^2\, r \cos^2 \phi - 2\, n\, r^2 \cos^2 \phi \frac{d\, \theta}{d\, t} \right\} d\, r$$

$$+\left\{\frac{d\Omega}{d\phi}-r^2\frac{d\phi'}{dt}-n^2r^2\sin\phi\cos\phi-2nr^2\sin\phi\cos\phi\frac{d\theta}{dt}\right\}d\phi$$

$$+\left\{\frac{d\Omega}{d\mu}-r^2\cos^2\phi\frac{d\theta'}{dt}-2nr\cos^2\phi\frac{dr}{dt}\right.$$

$$\left.-2nr^2\sin\phi\cos\phi\frac{d\phi}{dt}\right\}d\mu=0,$$

which is in accordance with Laplace's equation, *Méc. Cél.*, vol. i. p. 98. The remaining equations are to be deduced from the invariability of the mass of the element $d\,m$.

The elementary parallelopiped

$$r^2\cos\phi\,d\,r\,d\,\phi\,d\,\mu$$

is bounded by the sides

$$MA=d\,r,\qquad MB=r\,d\,\phi,\qquad MC=r\cos\phi\,d\mu,$$

the coordinates of the point M being $r,\ \phi,\ \mu,$

———	A	—	$r+d\,r,\ \phi,\ \mu$
———	B	—	$r,\ \phi+d\,\phi,\ \mu$
———	C	—	$r,\ \phi,\ \mu+d\mu.$

By reasoning similar to that employed in the *Traité de Mécanique*, vol. ii. p. 671, the following equation may be obtained, which is equivalent to a transformation of equation (D):

$$\frac{d\varrho}{dt}+\frac{d.\varrho r'}{dr}+\frac{d.\varrho\phi'}{d\phi}+\frac{d.\varrho\mu'}{d\mu}+\frac{2\varrho r'}{r}-\rho\frac{\sin\phi}{\cos\phi}\phi'=0,$$

or

$$\varrho'+\varrho\left\{\frac{dr'}{dr}+\frac{d\phi'}{d\phi}+\frac{d\mu'}{d\mu}+\frac{2r'}{r}-\frac{\sin\phi}{\cos\phi}\phi'\right\}=0.$$

For incompressible fluids, when the effect of changes of temperature is neglected, $\varrho'=0$ separately, and

$$\frac{dr'}{dr}+\frac{d\phi'}{d\phi}+\frac{d\mu'}{d\mu}+\frac{2r'}{r}-\frac{\sin\phi}{\cos\phi}\phi'=0,$$

which equation agrees with that given by Laplace, *Méc. Cél.*, vol. i. p. 101.

If τ denote the temperature, Fourier has shown that

$$\frac{d\tau}{dt}+\frac{d.u\tau}{dx}+\frac{d.v\tau}{dy}+\frac{d.w\tau}{dz}=\frac{K}{C}\left\{\frac{d^2\tau}{dx^2}+\frac{d^2\tau}{dy^2}+\frac{d^2\tau}{dz^2}\right\}\ \text{(E.)}$$

and if e denote the temperature which corresponds to a given temperature b,

$$\varrho = e\{1 + h(\tau - b)\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (F.)$$

K, C, and h being constants. *Mémoires de l'Institut*, vol. xiii. p. 519. When the temperature varies, the two last equations supply the place of the equation $\rho' = 0$.

The left hand side of the equation (E.) is of the same form as equation (D.), p. 25; hence by the help of a known transformation it is easy to transform equation (E.) to polar coordinates, and we obtain

$$\frac{d\tau}{dt} + \frac{d \,.\, \tau r'}{dr} + \frac{d \,.\, \tau \phi'}{d\phi} + \frac{d \,.\, \tau \mu'}{d\mu} + \frac{2\tau r'}{r} - \tau \frac{\sin\phi}{\cos\phi}\phi'$$

$$= \frac{K}{C r}\left\{\frac{d^2 \,.\, r\tau}{dr^2} + \frac{1}{r^2\cos^2\phi}\left(\frac{d^2 \,.\, r\tau}{d\mu^2}\right) + \frac{1}{r^2\cos^2\phi}\left(\frac{d \,.\, \cos\phi\,\frac{d \,.\, r\tau}{d\phi}}{d\phi}\right)\right\} \quad (E.)$$

The general equations of the motion of fluids have not yet been successfully applied to problems even of less difficulty than that of the tides, which is complicated by the irregular shape of the channel in which the tide-wave travels, and by the resistance which it meets with in its passage. An improvement, however, of theory as regards single observations, or for the purpose of prediction, is scarcely wanted, except as regards the fluctuations of the *establishment*, on account partly of the inevitable difficulty attendant upon observations of the time and height of high water, and partly on account of the derangement produced by causes which are at present far beyond the reach of analysis, such as winds and the varying atmospheric pressure. But when the averages of numerous observations are employed, it is evident that in the instance which I have adduced p. 20, and perhaps also in some others, the *equilibrium theory* appears at least to be insufficient. Its general agreement with the phænomena, to which I have adverted on former occasions, is extremely remarkable, and the merit of Bernoulli's investigation does not seem to have been sufficiently appreciated. But whether or not Bernoulli's theory may soon receive improvement, at all events the approximation is generally so close that I have thought it desirable constantly to compare the results afforded by the observations with those deduced from his expressions. Moreover, the results given in the tables have been laid down in diagrams, by which means their relation to each other and to theory is better perceived. The advantages of this method, of which

remarkable instances might be adduced *, have long been felt, but there can be little doubt that its more general application to questions depending for their illustration upon extensive series of irregular numbers, particularly those of meteorology and statistics (such as variations in prices, in the population, &c.), would greatly assist in developing relations at present obscure.

It appears from our examination that the establishment and mean height of high water are liable to slight fluctuations, which baffle at present our attempts to obtain extreme accuracy in tide predictions. This subject seems to deserve attention.

I have now endeavoured briefly to advert to those parts of the subject which appear to require further elucidation, in the hope that they may attract the attention of those whose command of analysis may enable them to remove the difficulties which still remain to be surmounted, and I have mentioned some of the facts which appear to me to result from these laborious calculations, which never could have been undertaken but for the interest which has been felt in the subject by some of the most distinguished members of the Association, particularly by Mr. Whewell, and but for the pecuniary grants which have at different times been devoted to this object. I hope that when the results are carefully examined which have been published in the *Philosophical Transactions*, they will not be found disproportionate in value to the great labour and expense which has been required for their attainment.

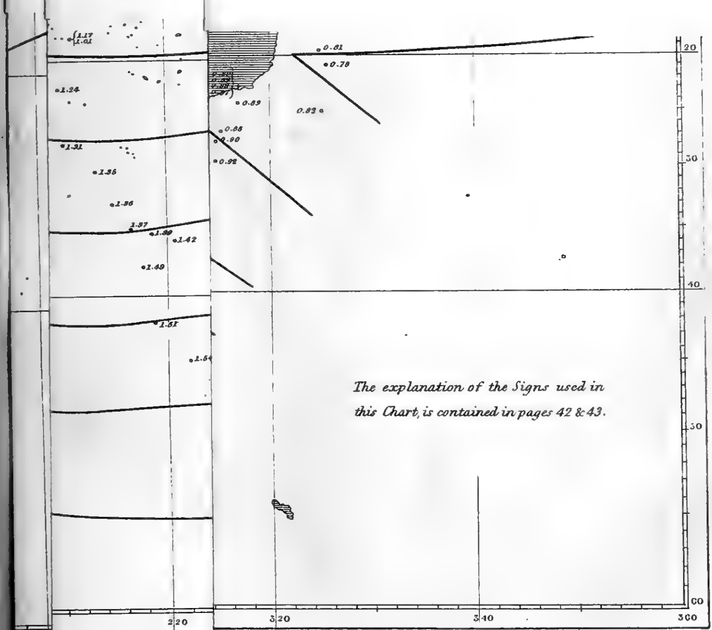
I have lately received, through the kindness of M. Arago, the printed Brest Tide Observations from January, 1807, up to the end of December, 1835. It now therefore remains to be considered whether by pursuing further this inquiry in the same manner other important facts can be elicited from the Brest observations. I was formerly extremely anxious to obtain access to these observations: first, because I understood that they were† in print; secondly, because the tide there is *single*; thirdly, on account of the classical interest which attaches to these observations, from being the foundation of the remarks connected with this subject by Laplace in the *Mécanique Céleste*; and fourthly, because the Brest observations extend throughout the same period as those made at the London Docks, which we have employed in our former discussion, Bakerian Lecture, 1836. But I am not inclined to think that a discussion of the Brest observations would now lead to results presenting any important

* *E.g.* Sir J. Herschel's determination of the orbits of double stars.

† We have felt great inconvenience in employing MS. observations; moreover, if the observations which we used were in print, greater facilities would exist for verifying our results.

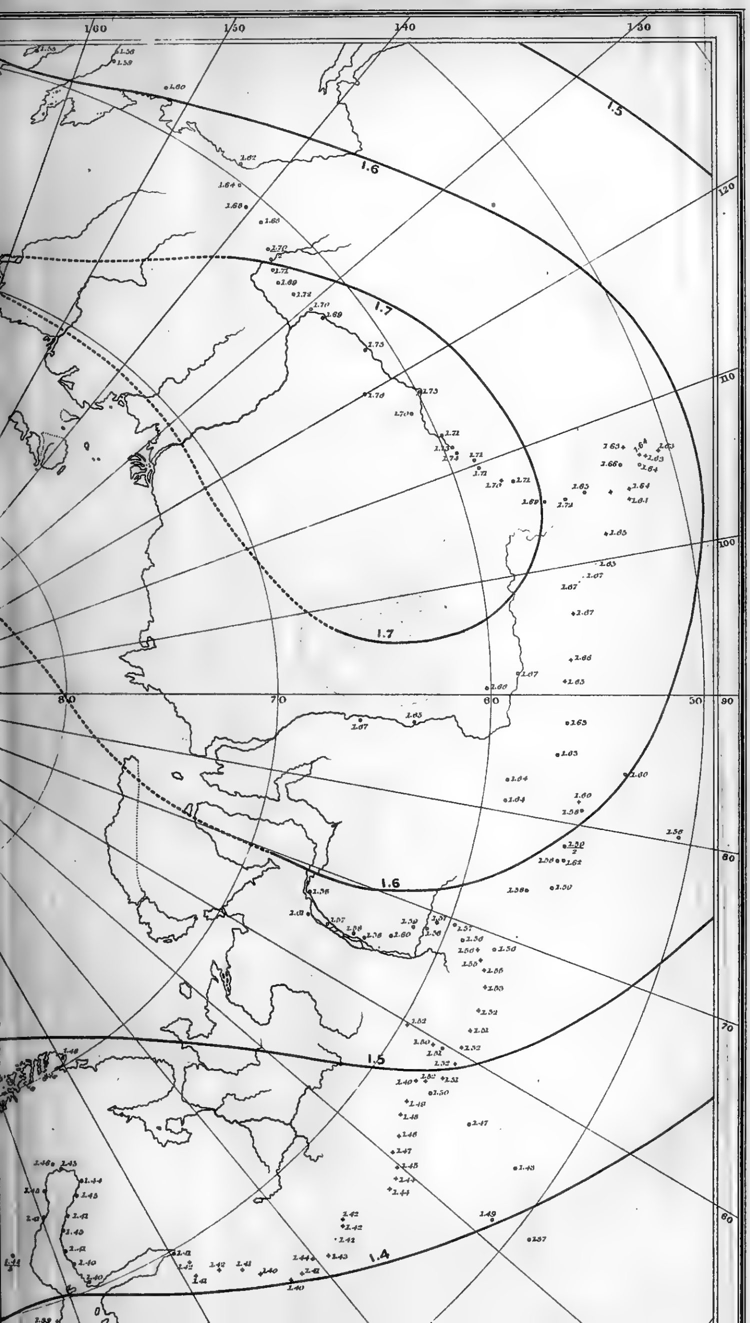
feature differing essentially from those which are afforded by the discussions which I have already completed of the London and Liverpool observations. But it would certainly be desirable to determine the semi-menstrual inequality in the height at Brest, that is, the constants D and E; this may be done from a year's observations. I determined some time since the semi-menstrual inequality in the interval for that place. See *Phil. Trans.* As the Brest observations extend throughout the same time as those of the London Docks which we have employed, the *same tides* might be discussed, and thus the influence of local circumstances and the resistances which the tide meets with in its progress from Brest to London might be clearly ascertained. I confess, however, I am not sanguine that any advantage would now be gained sufficient to compensate for the great labour and expense which the discussion would require.

3



J.Gardner, sc. Regent Str. London

CHART exhibiting the Observations of the Magnetic Intensity between the Latitudes of 60 N & 60° S



160
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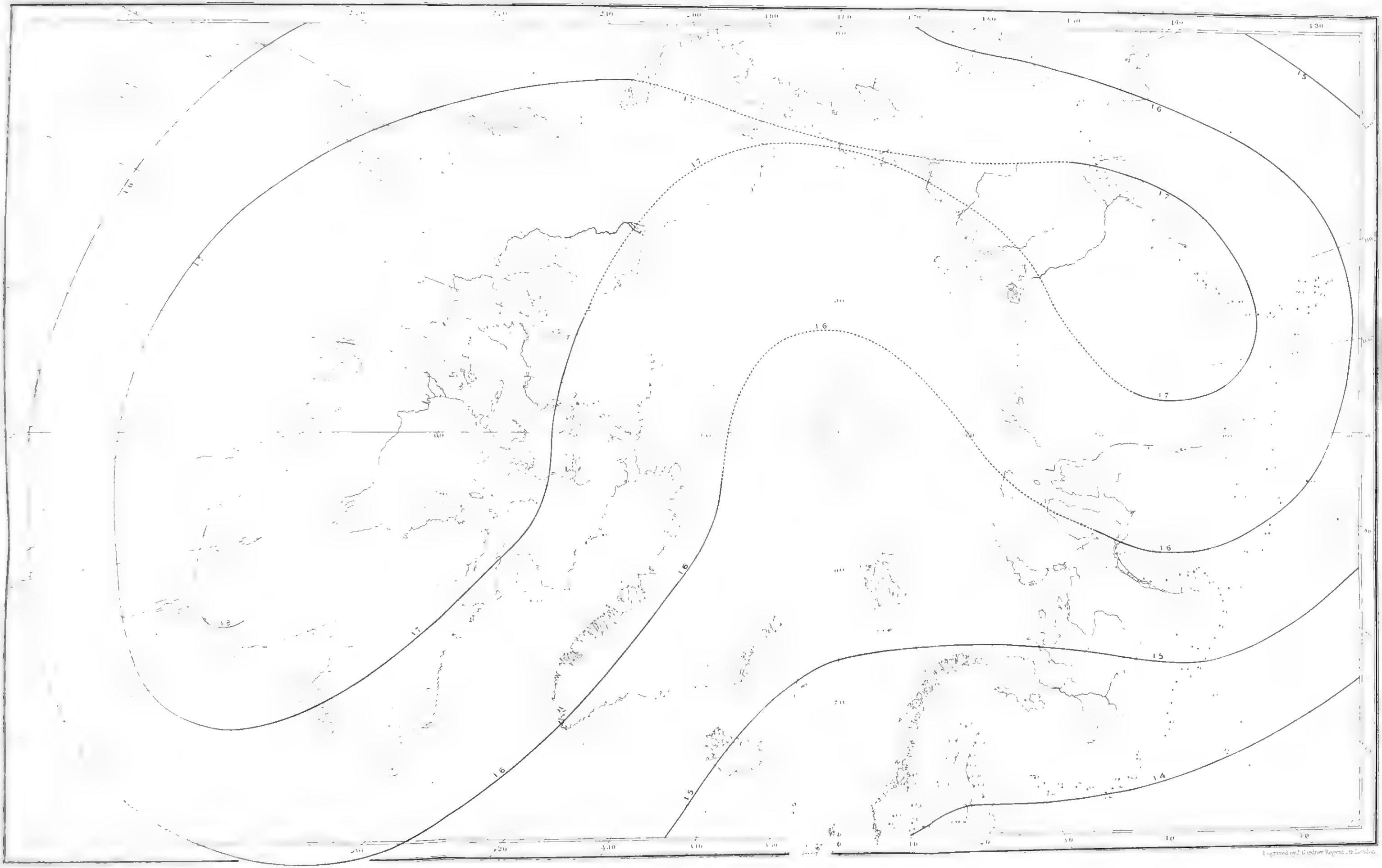
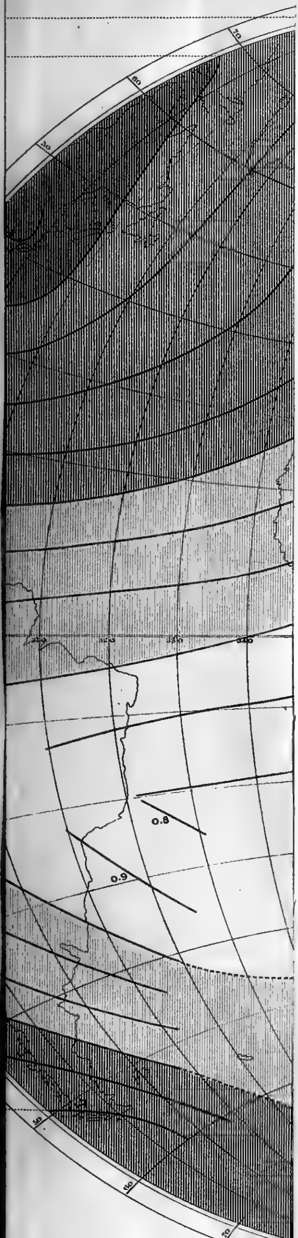
NORTH POLAR CHART exhibiting the Observations of MAGNETIC INTENSITY.



chibiting the unequal distributior



MAP of the WORLD *divided into Hemispheres by a plane coinciding with the meridians of 100° & 280° E of Greenwich, exhibiting the unequal distribution of the* MAGNETIC INTENSITY *in the two Hemispheres*

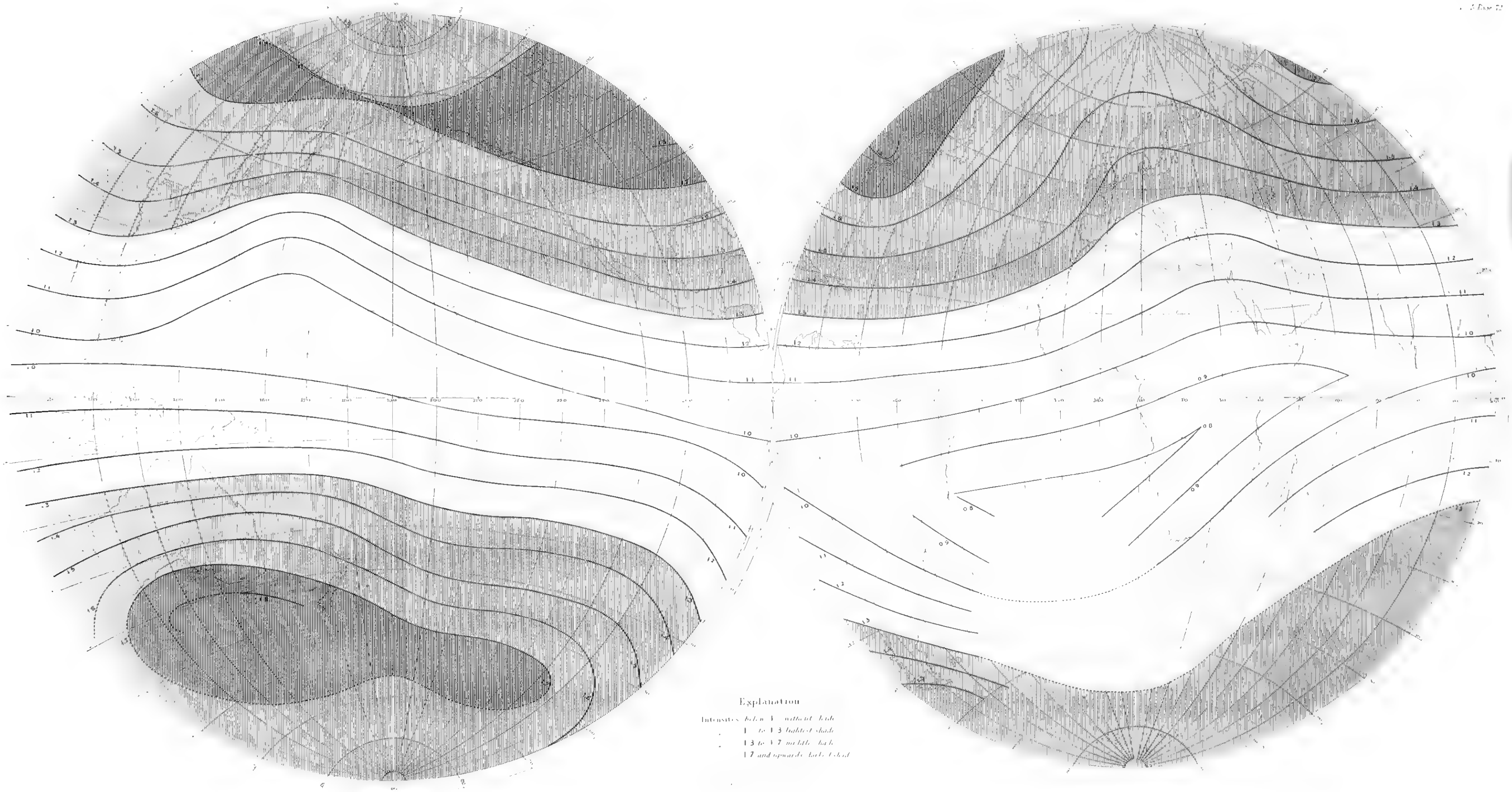
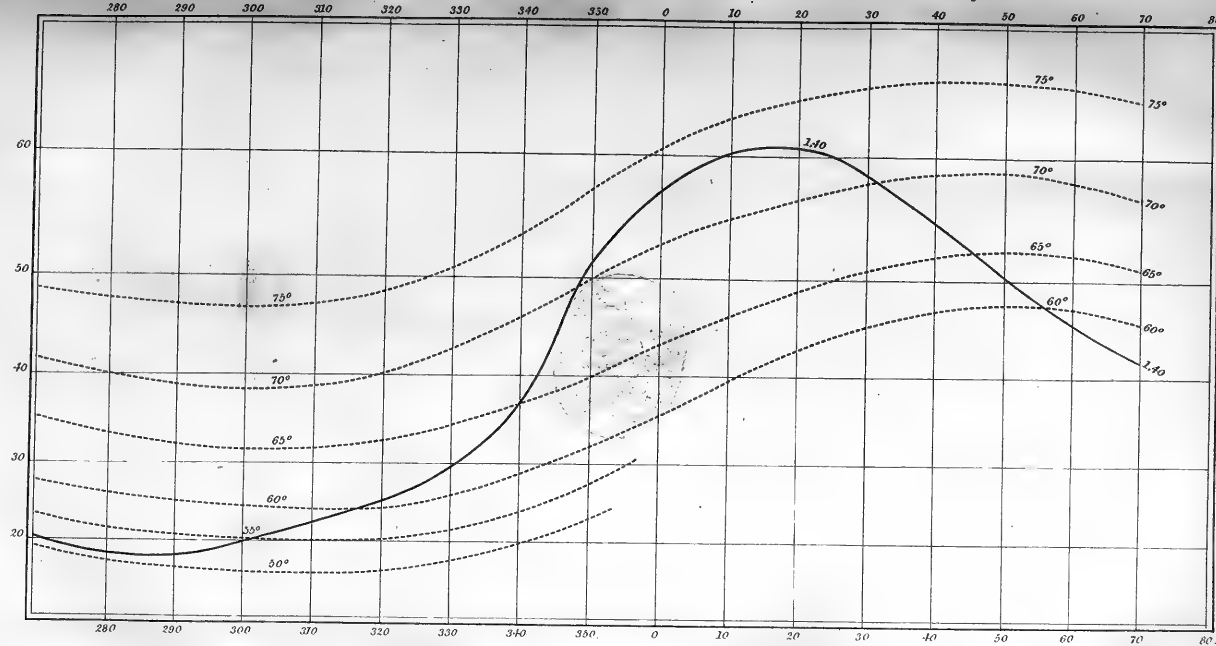
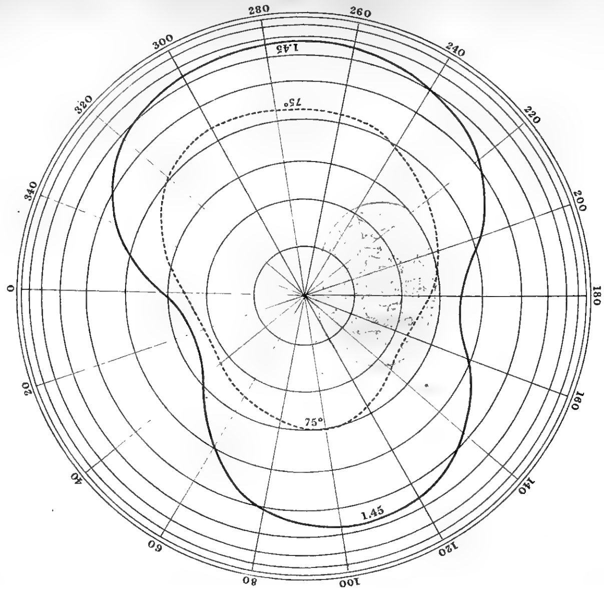


Diagram illustrating the non-parallelism of the isoclinal and isodynamic lines



Engraved by J. Gardner, Regent St. London.

Orthographic Projection of the Northern Hemisphere.



Isoclinal Line of 75° .... Isodynamic Line of 1.45 ———

On the difference between the Composition of Cast Iron produced by the Cold and the Hot Blast. *By* Thomas Thomson, M.D., F.R.S., L. & E., *&c.*, *Professor of Chemistry, Glasgow.*

At the meeting of the Association last year in Bristol, considerable difference of opinion was entertained respecting the advantages said to be obtained by heating the air before it is introduced into the furnaces in which iron is smelted, and it was finally admitted by all parties that the only unexceptionable mode of determining the question would be to institute a set of experiments to determine the relative qualities of hot and cold blast iron, and to make a comparative set of analyses of each sort in order to determine whether any, and what, differences exist in their chemical composition. Messrs. Hodgkinson and Fairbairn, of Manchester, undertook to make a comparative set of experiments on each sort, and Mr. Fairbairn stated the result of their experiments in the mechanical section of the Association. A committee was appointed by the chemical section to investigate the chemical composition of hot and cold blast iron. I had the honour of being named one of the members of that committee. I have accordingly made a certain number of analyses, and my object in this paper is to state the results which I have obtained. I do not know what has been done by the other members of the committee; I was at too great a distance from all of them to enable us to operate together; I therefore take it for granted that the object in view, when individuals living at such distances from each other were named together, was that each individual should make experiments on the iron made in his neighbourhood; and that the section, by comparing together all the results, might have it in their power to come to a proper conclusion respecting this most important subject.

A great deal of cast iron, and a considerable quantity of bar iron is now made in the neighbourhood of Glasgow. Probably the amount last year was not far short of 200,000 tons. It is well known that Glasgow is surrounded by one of the richest coal-fields in Britain. The coal is not only abundant, but of excellent quality, and the iron ore fortunately exists in great abundance, stratified or in nodules in the coal measures. The ore is always a *carbonate of iron*, never absolutely pure, and varying considerably in this respect even when we examine dif-

ferent specimens from the same bed. I have analyzed above thirty specimens at different times, generally selected with some care, as the object in view was to determine the average goodness of various beds of this ore, that the smelter might have it in his power to choose the best for his purpose.

In general some notion may be formed of the goodness of the ore by taking its specific gravity; the heaviest samples being the best. But this rule is not without exceptions; the specific gravity of some of the best specimens being diminished by an admixture of coal. The specific gravity of pure crystallized carbonate of iron is 3·829. Now the heaviest iron stone which I have met with in the neighbourhood of Glasgow has a specific gravity of 3·3801. It contains 83·85 per cent. of carbonate of iron. The remaining 16·15 parts consist of carbonate of lime, carbonate of magnesia, silica, alumina, and coal. A bed of iron stone near Airdrie is known by the name of Mushet's black band, because it was discovered by that gentleman, or at least its value was first pointed out by him. It contains 85·44 per cent. of carbonate of iron, which exceeds that from Crossbasket above stated, yet its specific gravity is only 3·0553. It may be worth while to state the composition of this black band, because it will show the foreign bodies always present, in greater or smaller quantity, in the clay iron stone of this district.

Carbonate of iron	85·44
Carbonate of lime	5·94
Carbonate of magnesia	3·71
Silica	1·40
Alumina	0·63
Peroxide of iron	0·23
Coaly matter	3·03—100·38

The quantity of silica and alumina in this particular band is unusually small, amounting only to about 2 per cent. In some specimens of clay iron stone which I have analyzed the alumina and silica amounted to 45 per cent. Mushet's black band contains no sensible traces of manganese. But in general that metal may be discovered, though never in great quantity, in the clay iron stone belonging to the Glasgow coal-field. There is a bed of iron stone near Johnston, which contains 84 per cent. of carbonate of iron; but its lime and magnesia being very small in amount, the silica and alumina together constitute 12·4 per cent. and the coaly matter 1½ per cent.

The lightest specimen of clay iron stone which I have met with in the neighbourhood of Glasgow had a specific gravity of 2·285 owing to the great quantity of coal, no less than 21·71 per cent., with which it was mixed. Its constituents were

Carbonate of iron	29·03
Carbonate of lime	1·52
Carbonate of magnesia	3·59
Coal	21·71
Silica	24·76
Alumina	20·10—100·71

If we abstract the coal, the carbonate of iron will amount to 37 per cent. of the ore. In another specimen of the same band containing $5\frac{1}{2}$ per cent. of coal, I found 62 per cent. of carbonate of iron.

It is remarkable that the proportion between the silica and alumina in the two specimens was quite different. In the first there were $12\frac{1}{2}$ atoms silica to 9 atoms of alumina, and in the second $12\frac{1}{2}$ atoms silica to 2 of alumina. This seems to show that the clay in the clay iron stone does not owe its existence to the decomposition of any mineral consisting of a definite compound of silica and alumina.

The existence of these foreign bodies in the clay iron stone, from which the cast iron subjected to analysis was derived, will enable us to understand the source of certain substances from which no cast iron hitherto examined is free. The ore, before it is put into the furnace, is always roasted, which drives off the carbonic acid from the carbonate of iron, and thus reduces the weight of the ore, at an average, about 31 per cent.

It is also mixed with carbonate of lime, which has the well-known property of fusing with clay into a liquid glass when sufficiently heated. This removes the clay from the ore, and enables the oxide of iron to come in contact with the ignited coals, which reduce it to the metallic state. I subjected the limestones used at most of the smelting houses round Glasgow to a chemical analysis. I need not observe that none of them was a pure carbonate of lime; for even the most transparent and colourless calcareous spar always contains a sensible quantity of foreign matter. The purest limestone I met with contained 94·6 per cent. of carbonate of lime. The foreign matter in all was silica, alumina, and peroxide of iron. In one only I found carbonate of magnesia, to the amount of 2 per cent., and in none could I detect the presence of manganese.

The coal used for fuel leaves, when incinerated, from 1 to 10 per cent of ashes. They are composed chiefly of silica, alumina, and oxide of iron. Coal is seldom quite free from iron pyrites. This enables us to account for the presence of minute quantities of sulphur in some of the specimens of cast iron analyzed.

When the Clyde iron works were established, about 50 years ago, to obtain 1 ton of cast iron ten tons of coals were required. This coal was previously converted into coke, by which process

it lost rather more than half its weight. The matter driven off by coking constituted in fact a most important part of the fuel, being the substances now well known under the names of coal-gas and naphtha. By diminishing the force with which the air was driven into the furnace, and by taking care that this air should be dry instead of moist, (in consequence of the water pressure originally employed,) and by some other minor improvements, the consumption of coals was reduced from 10 to 8 tons, or rather to 7 tons 13 cwt. for the production of one ton of cast iron.

The quantity of limestone employed for smelting a ton of cast iron was $10\frac{1}{2}$ cwt.

In the year 1833, when the mode of heating the air was brought to a state of tolerable perfection, and when the temperature of the air introduced was considerably above 607°, as it melted lead at the distance of an inch from the orifice, and the melting point of lead is known to be 607°, at that time coal was employed without being previously coked, and the quantity requisite for smelting a ton of cast iron was 2 tons 19 cwt., namely,

	Tons.	Cwt.	
For the furnace	2	0	
For heating the air	0	8	
For the steam engine	0	11	——2 19

The quantity of limestone used was reduced from $10\frac{1}{2}$ to 7 cwt.; and the product in iron was greater, and the daily quantity produced from a furnace was increased from 6 tons to 9 tons.

The expense of a ton of cast iron was in

1829	£4
1833	2 12

Produce in a month from 3 furnaces in

1829	500 tons cast iron.
1833	1010

When the Clyde iron works were originally established two furnaces produced only 14 tons of cast iron weekly. The produce was gradually increased to 30, 40, or even 70 tons a week; but after the introduction of the heated air the produce was as much as 130 tons a week. Indeed it was raised to almost 200 tons a week, but that was by the addition of another furnace.

Various explanations have been given of the way in which the heated air acts to produce these advantages. If we attend to the facts which I have just stated the true explanation will I think easily suggest itself.

When iron is smelted by the cold blast the coal requires to be coked, but when the hot blast is employed coking is unnecessary. In the latter case one half the quantity of coals is sufficient that is required in the former. Is it not evident from this that the whole oxygen of the air of the hot blast combines

with the fuel as soon as it enters into the furnace, and that the oxygen of the air of the cold blast is not all consumed immediately, but makes its way upwards, and is gradually consumed in its ascent, producing a scattered heat which is of no use in smelting the iron, but merely serves to consume the fuel. When the hot blast is used the combustion is concentrated towards the bottom of the furnace; with the cold blast it is much more diffused. Hence the reason of the saving of the coals in the former case, which constitutes the great advantage attending the new method.

This greater concentration of the combustion must subject the iron to a greater heat than when the combustion is more scattered. This accounts for the smaller quantity of limestone necessary for separating the clay; for the higher the temperature the smaller is the quantity of limestone necessary for the fusion of the clay. Hence also the greater rapidity of the process, and consequently the additional quantity of cast iron obtained from a furnace in a given time.

I think then we may conclude, that when the hot blast is used the heat is more concentrated, and consequently higher than when the cold blast is employed.

I shall now state the result of various analyses of cast iron, No. 1, smelted by means of cold, and also by means of hot air in the different iron works round Glasgow. These analyses were made in my laboratory, partly by myself and partly by Mr. John Tennent, upon whose accuracy and skill I could completely rely. All the iron works round Glasgow employ at present nothing but heated air, except the Carron Company, who are in the habit of making cast iron, No. 1, both by the hot and cold blast. I applied to the manager of the Carron works, and he very kindly supplied me with specimens of cast iron, No. 1, made by both processes. These specimens I carefully analyzed, and considered the comparison of the two specimens as very satisfactory, because the nature of the ore and the process was exactly the same in both cases, and because the Carron Company have the reputation of making cast iron of the very best quality. I had specimens of cast iron, No. 1, from the Clyde Iron Works which I had obtained before the new process was known, and consequently when nothing but the cold blast was employed; and I had also specimens of cold blast iron from Muirkirk, and some which had been given me as Swedish cast iron.

I shall now point out the differences which were observed between cast iron, No. 1, made by the cold and the hot blast.

1. The specific gravity of cast iron smelted by the cold blast is less than that of cast iron by the hot blast.

The following are the specific gravities of eight specimens of cold blast iron:—

1st. Muirkirk	6·410
2nd. Ditto	6·435
3rd. Ditto	6·493
4th. Ditto	6·579
5th. Ditto	6·775
6th. From pyrites	6·9444
7th. From Carron	6·9888
8th. Clyde Iron Works	7·0028

The specific gravity of the Muirkirk iron is considerably less than of that smelted at Carron and the Clyde Iron Works; the mean of the 8 specimens is 6·7034.

It has been hitherto supposed that the difference between cast iron and malleable iron consists in the presence of carbon in the former, and its absence from the latter; in other words, that cast iron is a carburet of iron. But in all the specimens of cast iron which we analyzed we constantly found several other ingredients besides iron and carbon. Manganese is pretty generally present in minute quantity, though in one specimen it amounted to no less a quantity than 7 per cent.; its average amount is 2 per cent. *Silicon* is never wanting, though its amount is exceedingly variable, the average quantity is about $1\frac{1}{5}$ per cent.; some specimens contained $3\frac{1}{5}$ per cent. of it, while others contain less than a half per cent. Aluminum is very rarely altogether absent, though its amount is more variable than that of silicon. Its average amount is 2 per cent.; sometimes it exceeds $4\frac{1}{2}$ per cent., and sometimes it is not quite $\frac{1}{5000}$th part of the weight of the iron.

Calcium and magnesium are sometimes present, but very rarely, and the quantity does not much exceed $\frac{1}{5}$th per cent. In a specimen of cast iron which I got from Mr. Neilson, and which he had smelted from pyrites, there was a trace of copper, showing that the pyrites employed was not quite free from copper; and in a specimen from the Clyde Iron Works there was a trace of sulphur. The following table exhibits the composition of six different specimens of cast iron, No. 1, analyzed in my laboratory, either by myself or by Mr. John Tennent.

	Muirkirk.	Muirkirk.	Muirkirk.	Pyrites.	Carron.	Clyde.	Mean.
Iron	90·98	90·29	91·38	89·442	94·010	90·824	91·154
Copper	——	——	——	0·288	——	——	
Manganese	——	7·14	2·00	——	0·626	2·458	2·037
Sulphur	——	——	——	——	——	0·045	
Carbon	7·40	1·706	4·88	3·600	3·086	2·458	3·855
Silica	0·46	0·830	1·10	3·220	1·006	0·450	1·177
Aluminum	0·48	0·016	——	3·776	1·032	4·602	1·651
Calcium	——	0·018	0·20	——	——	——	
Magnesium	——	——	——	——	——	0·340	

The constant constituents of cold blast cast iron, No. 1, are iron, manganese, carbon, silicon, and aluminum. The occasional constituents are copper, sulphur, calcium, and magnesium. These occur so rarely, and in such minute quantity, that we may overlook them altogether.

The constant constituents occur in the following mean atomic proportions :—

22	atoms iron	= 77·00
$\frac{1}{2}$	atom manganese	= 1·75
4·36	atoms carbon	= 3·27
1	atom silicon.	= 1·00
$1\frac{1}{8}$	aluminum	= 1·40—84·42

If we unite the iron and manganese, and consider them as acting the part of basis, to which the carbon, silicon, and aluminum unite in definite proportions, we have $22\frac{1}{2}$ atoms iron and manganese; $6\frac{1}{2}$ atoms carbon, silicon, and aluminum, or $3\frac{1}{2}$ atoms iron and manganese; 1 atom carbon, silicon, and aluminum. When we compare the different specimens analyzed, we observe a considerable difference in the constitution of each. In one specimen the iron and manganese were to the carbon, silicon, and aluminum, in the proportion of 2·41 atoms of the former to 1 of the latter; in another specimen as 8·87 to 1. Now both of these specimens were from Muirkirk. These differences doubtless depended partly on the ore, partly on the fuel, and partly on the heat employed. They account perfectly for the different properties of cast iron.

But the mean of the whole gives cold blast cast iron, No. 1, composed of $3\frac{1}{2}$ atoms iron, 1 atom carbon, silicon, and aluminum; and the proportions of these three constituents are very nearly 4 atoms carbon, 1 atom silicon, and 1 atom aluminum; so that the cold blast cast iron of this country consists of 21 atoms iron, with a little manganese, 4 atoms carbon, 1 atom silicon, 1 atom aluminum.

2. I examined only one specimen of cast iron, No. 2. It was an old specimen, said to have come from Sweden, but I have no evidence of the correctness of this statement. Its specific gravity was 7·1633 higher than any specimens of cold blast iron, No. 1. Its constituents were,

Iron	93·594
Manganese	0·708
Carbon	3·080
Silicon	1·262
Aluminum	0·732
Sulphur	0·038—99·414

The presence of sulphur in this specimen leads to the sus-

picion that it is not a Swedish specimen; for as the Swedish ore is magnetic iron, and the fuel charcoal, the presence of sulphur in the iron is very unlikely*.

In this specimen the atoms of iron and manganese are to those of carbon, silicon, and aluminum in the proportion of $4\frac{1}{2}$ to 1, instead of $3\frac{1}{2}$ to 1, as in cast iron, No. 1.

The atoms of carbon, silicon, and aluminum approach the proportions of 7, 2, and 1, so that in cast iron, No. 2, judging from one specimen, there is a greater proportion of carbon compared with the silicon and aluminum, than in cast iron, No. 1.

Mr. Tennent analyzed a specimen of hot blast iron, No. 2, from Gartsherry. Its specific gravity was 6·9156, and its constituents,

		Atoms.	
Iron	90·542	25·86	3·72
Manganese	2·764	0·78	
Carbon	3·094	4·05	1·
Silicon	0·680	0·68	
Aluminum	2·894	2·31	
Sulphur	0·023	0·011	
	99·997		

So that it resembles cast iron, No. 1, in the proportion of its constituents. The carbon is almost the same as in cold blast iron, No. 2, but the proportion of aluminum is four times as great, while the silicon is little more than half as much. The atomic ratios are, carbon 4· ; silicon, 0·67; aluminum, 2·28.

3. Five specimens of hot blast cast iron, No. 1, were analyzed. Two of these were from Carron, and three from the Clyde Iron Works, where the hot blast originally began, and where, of course, it has been longest in use. The specific gravity of these specimens was found to be as follows:—

1st. From Clyde Works	7·0028
2nd. From Carron	7·0721
3rd. From Carron	7·0721
4th. From Clyde Works	7·1022
Mean	7·0623

It appears from this that the hot blast increases the specific gravity of cast iron by about $\frac{1}{22}$nd part. It approaches nearer the specific gravity of cast iron, No. 2, smelted by cold air, than to that of No. 1.

The following table exhibits the constituents of these 4 specimens.

* I have been told by Mr. Mushet that the Swedes add sulphur to their iron, No. 2.

	Clyde.	Carron.	Carron.	Clyde.	Clyde.
Iron	97·096	95·422	96·09	94·966	94·345
Manganese	0·332	0·336	0·41	0·160	3·120
Carbon	2·460	2·400	2·48	1·560	1·416
Silicon	0·280	1·820	1·49	1·322	0·520
Aluminum	0·385	0·488	0·26	1·374	0·599
Magnesium	——	——	——	0·792	——
	100·55	100·466	100·73	100·174	100·

The mean of these analyses gives us,

		Atoms.	
Iron	95·584 or	27·31	6·5
Manganese	0·871 or	0·249	
Carbon	2·099 or	2·79	1·
Silicon	1·086 or	1·086	
Aluminum	0·422 or	0·337	
	101·285		

Or, in the proportion of $6\frac{1}{2}$ atoms of iron and manganese to 1 atom of carbon, silicon, and aluminum. In the cold blast cast iron, we have,

	Iron.	Carbon, &c.
In No. 1	$3\frac{1}{2}$ atoms	1 atom.
In No. 2	$4\frac{1}{2}$	1 —
In hot blast	$6\frac{1}{2}$	1 —

Thus it appears that when iron is smelted by the hot blast its specific gravity is increased, and it contains a greater proportion of iron, and a smaller proportion of carbon, silicon, and aluminum than when smelted by the cold blast.

The atoms of carbon, silicon, and aluminum are to each other nearly in the proportions of 12, 5, and 2; so that the proportion of silicon compared with the carbon is nearly twice as great in the hot blast iron as in the cold blast.

These are consequences that might have been anticipated from the theory of the process, as I have explained it in a preceding part of this paper.

As to the qualities of the two kinds of iron I do not consider my experiments as calculated to enable us to draw any consequence of much importance. Hot blast iron is obviously purer than cold blast iron. It is said by several of the Glasgow steam engine makers whom I have consulted on the subject, that the iron by the hot blast is not so tough as that made by the cold blast; and one very extensive house in Glasgow, in order to obviate this objection, is in the habit of adding a little Welsh iron to the hot blast iron before casting, and this I have been assured by the manager of the works obviates the defects.

4. An analysis of a specimen of cast steel, manufactu[illegible] in the neighbourhood of Glasgow, from the best Dannemor[illegible] [illegible]on, was made by Mr. Tennent, and perhaps it may be worth while to state the results obtained.

Its specific gravity was 7·8125, and its constituents,

		Atoms.
Iron	99·288	55·7 (Iron and Manganese)
Manganese	0·190	
Carbon	0·388	1·
	99·866	

Or it contains 56 atoms of iron united to 1 atom of carbon. He could not detect the least trace of either silicon or aluminum in this steel. Is it not probable that the reason why Dannemora iron answers so well for making steel is that it contains no sensible portion of silicon and aluminum; and that the presence of a notable quantity of these substances in British iron is the reason why it is so ill fitted for being converted into good steel?

Appendix.

A quantity of hot and cold blast iron was made in the same furnace at the Level Furnaces, Brierly Hill, Staffordshire, with the same proportions of ironstone and limestone, with the addition of one-half more coal, necessary to compensate for the deficiency of power in the furnace when blown with cold air. These products were tried with the following results:

1. Two bars of cast iron $\frac{9}{8}$ths inch square were melted in a crucible from pig iron, No. 1, the first cold blast and the second hot blast; both broke when exposed to a pressure of 2040 lbs.

2. $\frac{7}{8}$ths inch cable bolts were made from the hot blast iron No. 1. These cable bolts were exposed to the Liverpool proof, namely, a weight of 12 tons 5 cwt., without sustaining any alteration; even a weight of 17 tons 18 cwt. produced no bad effect.

Another chain without studs $\frac{7}{8}$ths inch in diameter, made from the same hot blast iron, was proved to 22 tons, 7 cwt. 1 qr. 2 lbs., or to 12 tons, 11 cwt. 1 qr. 2 lbs. above the Liverpool proof, without sustaining any injury. These trials show that hot blast iron is at least as strong as cold blast iron.

Notice of the Determination of the Constant of Nutation by the Greenwich Observations, made as commanded by the British Association. By the Rev. T. R. Robinson, D.D.

It is now a century since Bradley, by his brilliant discoveries of the aberration of light, and the nutation of the earth's axis, became the founder of accurate astronomy. By them he not merely explained the seemingly anomalous movements which, though noticed by others before him, were first established by his observations on authoritative evidence, but he also demonstrated that a degree of precision, which the other astronomers of that time could scarcely conceive, was perfectly attainable. From the commencement of his career to the present day the impulse thus given has never failed, and each successive year has brought improvements to the construction of astronomical instruments, to the methods of observing, or, what is equally important, to the reductions by which these observations are made available to science.

Yet it must be acknowledged that in respect of both aberration and nutation nothing was added to the researches of Bradley till within a few years, when Struve, Brinkley, and Richardson resumed the inquiry as to the first, and contracted within very narrow measures the limits of its uncertainty. The second, of these astronomers also investigated the constant of nutation, and his result is generally adopted by British astronomers. In Germany, however, the authority of M. Bessel has given currency to a different value of this important element, deduced by Von Lindenau, and though the two differ only $\frac{1}{4}$ of a second, ($\frac{1}{1,700,000}$ of the telescope used in observing,) such is the accuracy now required that even this evanescent discordance is felt as a disgrace to astronomy. This stigma I trust is now removed by the work which the powerful aid of the Association has enabled me to perform, and of which it is my present object to give a brief notice to this section, the fuller details requiring a different mode of publication.

When an observer directs the telescope of his circle to a star, the distance from the pole or the zenith which he obtains is but crude ore, and much labour is required to obtain its precious contents. The refraction of the atmosphere prevents us from seeing it in its true place; *its* effect must be computed and corrected; the light by which we see it takes time to travel through

the telescope, which itself moves with the earth, and thus *aberrates* from the true direction; this too has been brought under our dominion. The stars themselves, though we call them fixed, are most of them in motion, each with its own proper movement, and with a period to which even geological cycles are probably but as moments. And the points of our own globe, to which we refer their positions, are anything but invariable; they are agitated with perpetual changes, some of great duration and extent, others minute in quantity and rapid in recurrence, all of which must be appreciated and known before we can record any history of the heavens at a given epoch.

Of these disturbances of the earth's axis the greater terms have long been known under the name of the precession of the Equinoxes, and our present knowledge of their laws and amount is satisfactory; of the remaining three, appropriately called nutations, one completing its course in a fortnight and never reaching $\frac{1}{10}$th of a second, is sufficiently determined by theory; another, semi-annual in period, and $\frac{1}{2}$ a second at its maximum, is also given by theory, and, independently, by Brinkley's admirable observations.

The third is of much greater magnitude, being about $9''$, and running through its changes in the time of a complete revolution of the moon's nodes, something more than 18 years; and its exact determination is the object of this communication. It is obvious, that if a star's distance from the pole be determined when the effect of this nutation increases it most, but without making any allowance for *its* effect, and if $9\frac{1}{4}$ years after, when of course the distance is most diminished, it be again observed, the difference of the results will be twice the total effect of nutation on that star, and from this the entire or the constant of nutation is of course known. But if after a second lapse of $9\frac{1}{4}$ years, when all has returned to its primary condition, we have a third set of observations, the conclusion is made much more certain; for thus all doubt is removed that might come from any proper motion of the star if it returns to its original place; or if not, the difference detects that proper motion, and gives its amount. Therefore, to succeed in this inquiry, it is necessary to have observations extending through at least the whole period of the nodes, made with the same instrument, and, if it were possible, by the same observer, or at least according to the same system. In quantities so minute as those we are considering, in operations so delicate in themselves, and so easily vitiated by errors that can scarcely be suspected, all precautions are necessary; and with the exception of the observations made at Greenwich, while the late Mr. Pond presided over that ob-

servatory, there are none existing which even approach the fulfilment of these conditions. Even in them there is much objectionable, but many years must elapse before they can be surpassed.

The Greenwich circle was for the first 12 years employed to measure distances from the pole; afterwards from the zenith; the zero of the former being given by comparing the observed and calculated places of known stars, the latter by combining direct and reflected observations. This in the present inquiry needed no change, but the other was inadmissible, and I restricted myself to the pole star alone. Of it 4000 observations were computed, by the aid of Bessel's admirable tables, retaining his values of declination, nutation, and proper motion, but with mine of aberration and refraction. Of the results more than 2000 could be combined above and below the pole to give the zero of polar distance. The others served to keep watch in the interval between these conjugate observations, and show if any change took place in the instrument. After 1826, observations of Polaris were less numerous, but the index corrections given by it were then combined with reflected observations.

The other stars were selected on this principle, that their altitudes should be such as to free them from the uncertainty of refraction; and that those observations only should be employed in which at least $\frac{2}{3}$ of the effect of nutation is exerted in polar distance. Of such there are but 15 to be found in the Greenwich collection with sufficient frequency, and even of these three have not yet completed their cycles. Four of them are not found in Bessel's tables, but are similarly reduced; and in all correction has been made for that slight nutation of which I spoke as of a fortnight's period. They afford about 8000 results, but only 6000 have been available, 1000 from an accident which occurred to the instrument in 1820, and vitiated the work of almost two years, and the rest from occasional want of corresponding observations of Polaris.

Each of these observations should be exactly represented by the calculated place of the star, were there no errors of observation or of reduction, and the difference gives *their* effects. In the present case we consider only three things as doubtful; the place of the star at some given epoch, as given by the catalogue employed, the star's motion, and Lindenau's nutation. The residue therefore is properly equated to these three quantities, and the equations are divided into three groups, corresponding to the maxima and intervening minimum (or *vice versâ*) of nutation. The three resulting equations determine these three errors, two of which are peculiar to each star, but the correction of nutation

is common to all, and each set should give it the same value. This is not rigorously the case, and the difference proceeds partly from accidental errors in bisecting the star or reading the divisions, but still more from causes which are as yet unknown, and whose influence is but beginning to be noticed. Lastly, the corrections thus obtained must be combined into a general mean according to the most probable method, attending to their different weights. In some stars nutation appears with a larger coefficient, some have been more frequently observed, and both these circumstances must be duly estimated in taking the mean.

These are my results. To increase Lindenau's nutation :

710	observations of	γ Draconis	give	+ 0·″28
776	———	α Lyræ	—	+ 0· 54
705	———	α Cygni	—	+ 0· 03
452	———	Arcturus	—	+ 0· 33
369	———	β Ursæ minoris	—	+ 0· 35
224	———	β Tauri	—	+ 0· 35
284	———	Aldebaran	—	+ 0· 31
239	———	α Arietis	—	+ 0· 31
279	———	α Coronæ	—	+ 0· 61
287	———	Pollux	—	+ 0· 54
267	———	Castor	—	+ 0. 52
190	———	α Persei	—	+ 0· 77

To diminish it :

397	observations of	η Ursæ	give	− 0·″29
403	———	Capella	—	− 0· 31
393	———	Polaris	—	− 0· 01

The mean of all being,

	+ 0.″257
	8· 977
Lindenau	9· 234

differing only 0·″016 from the number selected by Mr. Baily for the admirable catalogue which has already been so useful to astronomy, and which I trust by the aid of the Association may soon be increased far beyond its present extent*.

It remains to consider what errors may be supposed to affect this conclusion. Some may object that I have used with Mr. Baily the constant of aberration 20·36, instead of employing 20·50, which Mr. Richardson has so ably deduced from the

* Since reading this notice to the Association I have received the Greenwich observations for 1836, which enables me to complete the cycle for α Cygni, and to determine the proper motions of Castor and Pollux more correctly. These, and some other changes of less importance, have slightly changed my result, which is now considered by me to be 9·239.

Greenwich observations themselves. I fully admit its weight, but must remark, 1st, that for the star common to our computations, the maximum of aberration obtained differs too widely, in one case more than a second; secondly, that the mean of Richardson and De Lambre gives, $\begin{array}{c}20\cdot503\\ \underline{225}\\ 20\cdot364\end{array}$, almost identical with Brinkley and Struvè $\begin{array}{c}20\cdot370\\ \underline{20\cdot350}\\ 20\cdot360\end{array}$; and, thirdly, that the use of Mr. R.'s constant would scarcely have changed my result. In the case of γ Draconis, the most important in my list, I performed the computation with this value, and the change it produced was only $\frac{3}{1000}$ of a second.

As to the casual errors depending on the circumstances of observation, I find for this star, that the probable error of *one* observation = $\pm\ 0''\cdot96$, and therefore, by the theory of probabilities, it comes out an *even bet*, that as far as such errors are concerned the result given by it is not uncertain to $0''\cdot04$, and Lyræ has nearly the same probable error. Therefore, the slight discordances in my results proceed from other, and, as yet, unknown causes. Similar and greater discrepancies occur in Mr. Richardson's investigations, but it is curious that in Brinkley's researches on nutation, Capella, and α Cygni give results less than the mean; α Lyræ, β Tauri, and Castor above it.

It might seem that a more accurate conclusion is attainable by assuming the proper motion of the stars as known from comparison of Bradley's observations with those of recent date. This supposition would give the constant 9·181, 0·05 less than that given above; but I think it inadmissible, for these motions may not be uniform, and there may be changes in the instrument, the refraction, the observer, nay, even in the direction of gravity, as affected by local circumstances, which are functions of the time. Something of this sort does actually appear here. It is well known that Pond latterly believed in the existence of a general southern motion of the stars; and though Brinkley has shown most fully that this is imaginary, yet it is remarkable that the corrections of Bessel's proper motions, which my work has given, are, except in one instance, all negative. I infer from this that the Greenwich circle is undergoing some progressive change of figure, which makes it show polar distances too great for about 30 degrees south of the zenith; but if this be the case it is not likely long to elude the sagacity of Mr. Airy.

The declinations which I obtain from these Greenwich observations differ considerably from those deduced by Pond himself,

and given in the N. A. for 1834, but they agree closely with those of Bessel; they give the following corrections:

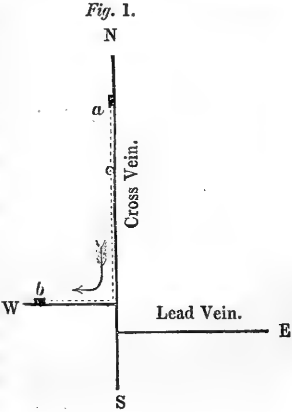
	Cor. N. A.	Cor. Bessel.
γ Draconis	− 0·97	− 0·08
α Lyræ	− 1·25	− 0·29
α Cygni	− 0·66	+ 0·43
Arcturus	− 1·82	+ 0·02
β Ursæ Minoris	− 0·61	+ 0·10
β Tauri	− 1·57	+ 0·98
Aldebaran	− 1·80	− 0·08
α Arietis	− 1·48	+ 0·02
α Coronæ	− 1·70	− 0·06
Pollux	− 1·51	+ 0·56
Castor	− 2·05	− 0·13
α Persei	− 1·80	− 0·99
η Ursæ	− 0·69	+ 0·20
Capella	− 2·13	− 1·02
Polaris	− 0·01	− 0·04
Mean	− 1·34	− 0·02

This seems to show that the difference between these celebrated catalogues arises solely from the different methods of reduction employed, and may excite a wish that the whole of Pond's Greenwich catalogue should undergo a similar revision.

Report of some Experiments on the Electricity of Metallic Veins, and the Temperature of Mines. By ROBERT WERE FOX.

IN fulfilment of the commission with which I was last year intrusted, it was my intention to have made some experiments on the electricity of metalliferous veins on a larger scale than I have yet done, and to have endeavoured to produce changes in the composition of bodies, by the long-continued action of electric forces, derived from this source. Other engagements have, however, interfered with the execution of these plans, and the only experiments of this nature which I have recently made have been confined to *Coldberry* and *Skeers* lead mines, situated near Middleton Teasdale, in the county of Durham. In the former, I obtained no decided results; and in the latter, the galvanometer indicated very feeble electrical action. There are seven E. and W. lead veins in this mine, contained in limestone, which are shifted from three to five fathoms to the right hand by a cross vein, having nearly a northern and southern direction. The cross vein contained more or less galena near some of the places of intersection; and a connection was made, by means of copper wires, between portions of ore in the cross vein, and others in one of the most productive of the east and west veins, when there appeared to be a feeble action from N. to W. (see ground plan, fig. 1). The parts connected, *a* and *b*, were about twenty fathoms distant from each other, and fifty fathoms under the surface.

Fig. 1.



A small stream of water gushing out of the vein was at 50° Fahr.

The ore in this mine was far from abundant, at least it did not occur in such large masses as are best calculated for experiments of this description; and the wire was not sufficiently long to admit of observations being made on the relative electric states of *parallel* veins.

These experiments, together with others which I made some years ago in other lead mines near Mold in Flintshire, tend to induce the belief that the electric action is much more feeble in lead veins when contained in limestone and sandstone

than in copper veins included in the lower rocks, such as granite and "*killas*" or clay slate. And here it may be remarked that the sulphurets of copper are more *electro-negative* than galena, which circumstance may have had some influence on the results.

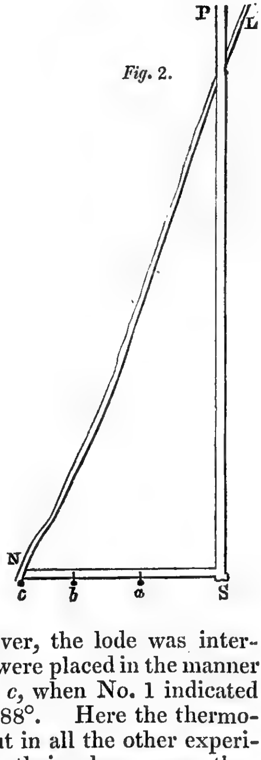
I wished to have made experiments on the electricity of some of the coal-beds which have been traversed and charred by the great basaltic dyke in the county of Durham, but my time and engagements did not well admit of my doing so. It is well known, that when coal is reduced to the state of a cinder it becomes a good conductor of voltaic electricity, although coal, in its natural state, does not possess this property, or even anthracite. A friend of mine having kindly sent me some specimens of the altered coal taken from Cockfield Fell Colliery, I found that most of them were incapable of conducting voltaic electricity, which unexpected circumstance may, perhaps, be attributed to their having undergone a degree of vitrification,—penetrated, possibly, by some siliceous matter, which their appearance indicated; and I am rather confirmed in this opinion from having since found that one of the pieces of native cinder from the same place is as good a conductor of electricity as coke, and it has a less vitrified appearance than the others. Here then we have the evidence of electricity in favour of the powerful action of the heated basalt on the contiguous coal deposits.

I have, on various occasions, endeavoured to show that the high temperature observed in the *lowest parts* of deep mines is in a great degree independent of accidental or extraneous causes not existing in the earth itself, and, indeed, that it is more often diminished by them than the reverse. It occurred to me that this point might be decided by burying the bulbs of different thermometers at various depths below the deepest excavations of mines, and I am indebted to the agents of *Levant* Tin and Copper mine, and of the *Consolidated* Copper mines, for having carried this plan into effect for me in their respective mines. The former mine is situated on the coast, in the parish of St. Just, and is worked in granite and "killas." Its depth is about 230 fathoms from the surface, and 200 fathoms below the level of the sea. A thermometer four feet long, and inclosed in a brass tube, had its bulb sunk in a hole three feet beneath the "*sump,*" or bottom of the deepest shaft, whilst another shorter thermometer was placed very near it, with its bulb inserted in a hole only about an inch deep. The former, which may be distinguished as No. 1, indicated a temperature of 80°, and the latter (No. 2) of 78·°5, both of them having been previously compared with a standard thermometer, and the needful correction applied. This part of the mine is in granite. The thermometer was afterwards placed in like manner in "killas," at the

western extremity of the deepest level or gallery, about 190 fathoms under the sea level, and four feet from the lode, when No. 1 showed a temperature of 78°, and No. 2, 72·°5 ; a stream of water which flowed into another part of this level to the eastward of the shaft, and in granite, was at 78·°5, and the air in the level only 67°.

The Consolidated Mines are situated in the parish of Gwennap, and nearly thirty miles to the eastward of Levant. The depth is 290 fathoms from the surface, and 237 below the level of the sea at half-tide; the rock is "killas." There is a "*cross-cut*," or gallery proceeding from the bottom of the deepest shaft (Pearce's), marked P.S. in the section Fig. 2, at right angles to the lode, which it intersects at N., the lode underlying towards the north L.N. The thermometers No. 1 and 2 were placed at *a*, 24 fathoms from N., the bulb of the former in a hole three feet deep, and that of the latter in another an inch deep, the holes having been filled round the thermometers with clay, &c. Under these circumstances No. 1 indicated a temperature of 85·°3, and No. 2 of 84°. The thermometers were then similarly arranged at *b*, ten fathoms from N., and No. 1 gave 86·°3, and the other 85°. These experiments were made before the cross-cut was completed as far as N. When, however, the lode was intersected at that place, both thermometers were placed in the manner already described in the lode itself at *c*, when No. 1 indicated a temperature of 92°, and No. 2 of 88°. Here the thermometers were kept only two hours, but in all the other experiments in both mines they remained in their places more than twenty-four hours; and when No. 1 was taken out of the deep holes, and allowed to stand awhile in the "cross-cut," the mercury always fell at least a degree. Only two men were at work at a time in or near this part of the mine. The increase of temperature in the lode, may, I conceive, be attributed to the greater facility afforded by it for the ascent of currents of warm

Fig. 2.



water from more considerable depths, and the difference between *a* and *b* to their relative proximity to the lode. The temperature of 85·°3 is at least 35° above the mean of the climate, and, therefore, it gives a ratio of increase equal to one degree in 49·6 feet, if calculated from the surface; and Levant Mine, which was 80° at the bottom, one degree in 46 feet, or they give one degree in 48 and 44 feet respectively, if estimated from ten fathoms under the surface.

The thermometers were likewise placed in holes, as before, in a superior level in the Consolidated Mines, 130 fathoms below the surface, when No. 1 indicated a temperature of 61°, and No. 2 of 61·°6. This difference in favour of the short thermometer was probably due to the influence of ascending currents of warm air and vapour on the surface of the rock; and such an explanation is not inconsistent with the opinion that the general temperature of the upper parts of the mine had undergone a diminution of its original amount, in consequence of the excavations below having interfered with the ascent of warm water, and promoted the drainage from above of that which was comparatively cold. For these reasons, and from the results obtained at the *deepest* parts of mines of various depths, I consider that the temperature of 61° is much below what it would have been had there been no inferior excavations; and I have evidence that in 1822, when the mine was only 150 fathoms deep, the water at the bottom of one shaft was at 76° and of another at 80°.

It is clear, I think, from all the experiments which have been made on the temperature of mines, that causes which are more or less local, and exist in the earth itself, have a powerful influence in modifying its degree, and in producing those anomalous results which have always characterised observations on subterranean heat. When it is considered how much the crust of the earth abounds with fissures or faults, and that warm water has a constant tendency to ascend through cooler portions of that fluid, and thus to produce upward and downward currents in the fissures and veins, it would indeed be surprising if such discrepancies did not exist even in the same vicinity, to say nothing of the greater or less influence of water percolating from the surface. Upon the whole, I am strongly of the opinion that the effect of the simple conducting power of rocks on the temperature, at depths hitherto attained, is very much superseded by that of the transporting property of water to which I have alluded. Indeed, I have long taken this view of the subject, and it has appeared to me to account very satisfactorily for the fact of the more compact rocks, such as granite, having been often found at rather a lower temperature than "killas" at given depths, and

both of them inferior in this respect to large porous lodes or veins*. Thermal springs may likewise, I conceive, be referred to the same cause, and it is well known that they are generally connected with fissures or faults; moreover, I may here remark that this property of fluids must more or less influence the temperature of water in Artesian wells, so that thermometrical experiments made in them are often rather calculated to prove the existence of subterranean heat than to ascertain its ratio of increase in descending from the surface.

Since the foregoing report was read at the geological section, I have obtained some results relative to the temperature of Tresavean Copper Mine from Captain Oats, who kindly made the experiments for me. The mine is worked almost wholly in granite, and is situated in the parish of Stythians, about three miles to the S.W. of the Consolidated Mines. The bulb of the thermometer No. 1 was buried 2 feet 10 inches, and that of No. 2 one inch under the surface of the rock at the different stations, their stems having in all cases been surrounded by clay pressed into the holes. The following were the results:

Depth in fathoms. from surface.	from sea level.		Experiments made. In air.	In the rock. No. 1.	No. 2.
			°	°	°
26	...	In granite 15 fathoms N. of lode, and 40 fathoms from "killas"	53·3	57·	52·8
200	170	In the lode, rock do., "killas," and three fathoms from granite	77·2	76·	75·5
200	170	In do. 10 fathoms from do.	77·7	76·	75·5
250	196	In lode contained in granite, and 60 fathoms from "killas"	83·2	82·5	82·
262	208	In lode, do., in 7 fathoms from do., being the bottom of the mine	85·5	82·5	82·

The last result gives a ratio of increase of 1° in 48 feet, calculated from the surface. It will be seen that the elevation of the latter, in reference to the sea-level, varies considerably in different parts of the mine.

* See Philosophical Magazine and Annals, 1831, vol. ix., p. 94.

Provisional Report of the Committee of the Medical Section of the British Association, appointed to investigate the Composition of Secretions, and the Organs producing them.

Part I.

The Committee appointed by the Medical Section of the British Association to investigate the chemical composition of glands and their respective secretions, have been prevented by different circumstances (amongst which have been the lamented death of one of their number, and the disturbed health of another) from rendering a complete report on the subject referred to them. They are desirous however of making such a statement of their progress as may invite the co-operation of animal chemists in the extensive and somewhat difficult field in which they find themselves engaged.

The manifest object of the investigation proposed to your committee has been to obtain, through the medium of animal chemistry in its present improved state, some further insight into the mysterious and vital process of secretion.

The terms in which this inquiry is proposed seem to give to it a particular direction, the reason for which may not be very obvious; and as they were suggested by one of your committee, it may not be amiss to assign here the reasons which occasioned this course to be pointed out: before proceeding to do so we will offer one remark in opposition to a generally received opinion respecting the process of secretion. It seems to be considered that in as much as this process is one in which vitality is concerned, it is removed from the province of chemistry; from this opinion we totally dissent, seeing that whatever changes are produced in the proportion and mode of combination of the elements of which bodies are composed, must, when not merely mechanical, be essentially chemical, and that the introduction of an agent, though it be no less important than the influence of life, does not in any degree detract from its chemical character. We have merely to consider that the elements both act and are acted upon under peculiar circumstances, which offer some analogy to what is seen when chemical elements are exposed to the influence of caloric or electricity; their inherent properties are not destroyed, but they are modified when they are placed under these influences; and as the investigation of chemical changes, in which the two influences just mentioned are concerned, has tended greatly to improve our knowledge in respect to them, so

we may reasonably hope that a similar result may be obtained from the investigation of the processes of nutrition and secretion going forward in living bodies, by regarding them as strictly chemical, even in those very modifications which vitality produces. When it is considered that during the activity of life the process of nutrition is constantly maintaining, even in the solid parts of animal bodies, molecular changes by which old materials are removed and new ones deposited, we must be led to presume *à priori*, that as the rejected particles are taken away in a state of perfect solution, they must find their way into those fluids which proceed from the particular part. In ordinary textures (by which we wish to be understood those which are not called glandular) we feel no hesitation in admitting that the rejected particles are carried away in the lymph and venous blood; but in glandular structures, and in parts which like them yield a peculiar secretion as well as return lymph and venous blood to the system, we have a third course into which some of the rejected particles may be expected to find their way. Now though it may be difficult or almost impossible to detect either in the venous blood or the lymph, any peculiarities which the addition of the rejected particles may give to the venous blood and lymph proceeding from particular parts, the case may be different when we investigate a particular secretion in which it seems probable that these particles may exist in a larger proportion, having a less admixture of the whole or some of the constituents of the general circulating fluid. The manifest properties of some secretions seem to lead to a similar conclusion *à posteriori*. The varieties which we find in pus produced in different parts of the body are among the most palpable examples of this kind. Pus from the brain has a peculiar consistence and colour resembling greenish cream, even where there has been no breaking down of the substance of the brain, by which that material might be grossly blended with it. When pus is formed in the immediate neighbourhood of the alimentary canal, and especially of the lower part of it, it possesses so strongly the fæcal odour, that it had been confidently believed that fæces had been mixed with it, until the absolute impossibility of such an occurrence had been demonstrated. Pus formed in the immediate neighbourhood of the toes possesses the peculiar odour of those parts, and a similar remark sometimes applies to matter formed in the axillæ.

The peculiar odour exhaled by different species of animals, and even by different individuals of the same species, dependent on differences of age and sex, appears to be another illustration of the principle which has been here suggested: for although

such peculiar odour may in some instances be referred to a special local secretion, as in the instances of the civet cat and musk deer, it cannot have escaped the observation of those who have been in the habit of dissecting the bodies of recently killed animals of different species, that these exhale not from one part only, but from every part internal as well as external, modified indeed by circumstances, a peculiar smell which is characteristic, and belongs both to the solids and fluids.

Another illustration of the influence of the character of parts upon the secretion which they produce may be seen about the mouth, where a slight excoriation or sore is apt to produce a considerable quantity of thin fluid secretion, which one can scarcely fail to regard in conjunction with that secretion which is poured into the mouth from the internal surface of those parts. The copious secretion from a blistered surface, when the subcutaneous cellular membrane is œdematous, is perhaps a phenomenon of the same character.

The chemical composition of secerning organs may influence that of their products independently of the particles which they may absolutely impart from their own structure. It may do so by a process similar to that which Thenard has pointed out as taking place when deutoxide of hydrogen comes in contact with fibrin; a process which that great chemist several years since pointed out as likely to throw light on the function of secretion. This idea has since been developed by Berzelius, who calls their action of contact the catalytic action, and argues that probably the contact of the blood with certain surfaces of the organs may produce some alteration in the arrangement of elements, and that the secretions may be thus catalytically formed from the blood.

It is probably to the operation of this principle that we may ascribe some phænomena, which, in addition to the circumstances which have already been mentioned, render it desirable to ascertain with accuracy the composition of solid parts in conjunction with that of their secretions. In some healthy, and in not a few morbid actions, we see that a new product, whether fluid or solid, is very much influenced by the character of the surrounding parts. Thus in the condensed cellular membrane in the neighbourhood of bone it sometimes happens that masses of bony matter are deposited, but are perfectly detached. The numerous instances which we see of ossification at the origins or insertions of muscles are probably referable to the same principle, although it must be admitted that these examples are not unexceptionable, since in them we have a continuity of structure. As a further illustration it may be noticed, that after the fracture of a bone,

the process by which the new bony matter necessary for union is produced, is often morbidly carried on in the matters which inflammation has deposited in the surrounding structures. The most striking illustrations are undoubtedly those which are presented by the heterologue structures, probably because of their being much more readily produced accidentally than the analogue. Thus we see that the natural structures in the neighbourhood of malignant tumours are apt to degenerate into a substance in some respects resembling that of the original tumour. In the neighbourhood of those tumours which are of slow growth, and of cartilaginous hardness, we often find the surrounding structures, but more especially the cellular membrane, partaking of the same character of hardness, though necessarily wanting the structural arrangement which characterizes the tumour itself. In the same way we find that those tumours which are composed of a soft and brain-like substance are surrounded by natural structures, which degeneration has converted into a nearly similar substance, or which have a similar matter deposited intersticially. Again, in those tumours which are remarkable for their black colour, and to which the name of melanosis has from this circumstance been applied, the surrounding structures become more or less deeply tinged with a black or dark-coloured material. This disease also presents us with a good illustration of the principle in a mode precisely the converse of the preceding example. There is, perhaps, no organ so liable to be affected with melanosis as the eye; and it may not unreasonably be suspected that it is the natural and healthy production of black pigment, performed by the choroid coat of this organ, which is the chief cause of this predisposition.

The anatomical structure of a secreting organ is one of the conditions in which it is essential to consider in an inquiry into the phænomena of secretion, although it cannot be imagined that it affects it by any merely mechanical separation. If it were possible, it would be desirable to ascertain, and to indicate by definite terms, the comparative degrees of vascularity, the proportion in which the ramifications of the three vascular systems are combined, and the rapidity of circulation. The comparative innervation of the part, although probably no less important, is perhaps still less exactly ascertained. To improve our knowledge on this point, it would be particularly desirable to ascertain not merely the number of nerves sent in proportion to the size of the organ, but also their origin, and the proportion in which they are derived from the ganglionic and cerebro-spinal systems; the degree of sensibility which they impart to the organ, the degree of uniformity or variation of function which may be observed in

the organ, and the conditions by which it may be influenced in this respect; also whether the nutrition resulting from the combined action of the vascular and nervous systems is steady or subjected to periodical or other variations.

Although we are at present very much in the dark upon most of these subjects, we may be convinced from various examples that the characters of a secretion are influenced by the texture of the organ which produces it. In those adventitious cysts which are liable to be formed in different parts of the body, but which are most frequent as well as most distinctly formed in the ovaries and in their vicinity, we find, that whilst they are of a thin and delicate texture the secretion is thin and aqueous or serous, but that when they have become a little thickened their secretion is thick, viscid, and mucous or albuminous. A similar transition, but in a less marked degree, may be seen in the serous membranes natural to the body, and also in the mucous membranes. Where these are thin and delicate, as in the case of the conjunctiva, and in the extreme branches of the bronchial tubes, their secretion approaches very closely to that of the serous membranes, whilst the thicker membranes which line the various portions of the alimentary canal produce large quantities of mucus. When chronic inflammation has thickened these membranes the quantity and viscidity of the mucus produced is notoriously increased.

In investigating the causes which operate in the production of animal secretions there are doubtless several points to be considered beside the chemical composition and anatomical structure of the parts producing them, and the composition of the fluid from which they are derived. Even after the secretion has been poured forth from the living solid, it is certain that it undergoes important changes by which its character is in many respects altered. Although these changes are in part to be ascribed to the material remaining under the influence of the living structure by which it is surrounded, and which may act both by abstraction and addition, nevertheless there are some modifications more immediately depending on the inorganized secretion itself. Such changes seem to be more particularly within the undisputed limits of animal chemistry in its present state, and we may reasonably expect to find their parallels or analogues in the changes which take place in dead matter apart from the living body. While some of these changes are undoubtedly brought about by the influence of air and moisture, by which the addition or subtraction of elements may be effected, in other instances the change seems to be more particularly

brought about by the alteration in the arrangement of the previously existing elements.

Amongst the changes taking place under one or other of these conditions in inorganic or dead matter, and wholly removed from the influence of life, and to which some parallels may probably be found in changes effected within the living body; the following examples may be pointed out by way of illustration. None are more notorious and familiar than those which take place in wine and other fermented liquors when kept in well-closed bottles. In some of these instances it may be said that the change is only mechanical, and the result of very slow deposition; yet there are unquestionably cases in which no deposition takes place; and the change, be it what it may, is undoubtedly effected in the chemical combination of the ultimate elements. Between these extremes there are mixed cases, as when crystals are deposited and gases liberated to occupy the upper part of the containing vessel. Amongst the long-neglected bottles which may sometimes be seen in a chemist's laboratory, we may occasionally observe the results of very slowly-effected changes in the combination of the enclosed elements exhibited in remarkable precipitates and in alteration in colour.

In the mineral kingdom, and more especially in rocks of volcanic origin, and possessing a cellular character, we may observe the most remarkable transfer and chemical combination of elements in the products, often beautifully crystallized, by which the cavities become more or less filled, notwithstanding the firm and apparently impenetrable character which the rock may possess. Amber may be adduced as another example furnished by the mineral kingdom, for it is doubtless whilst appertaining to this class that it has received the characteristics which distinguish it from the recent resins to which it is not only closely allied, but from which it is in all probability really derived. In this instance we have a material as impervious to water as the volcanic rocks before-mentioned. But the obvious change produced is in some respects different. Instead of a new substance, separated in distinct portions, the result of a transfer to sensible distances, we find an uniform change of substance throughout. There is perhaps no change in dead matter which is more interesting, from its relation to the subject before us, than the conversion of all the soft parts of animals into the peculiar fatty substance called adipocere, which takes place under exposure to certain circumstances, of which immersion in moisture appears to be the most important. It is worthy of note that this change seems to take place nearly alike in

different textures, such as skin, muscle, cellular membrane, and adipose substance; yet as it can hardly be supposed that they are all equally prone to it, it seems probable that its having commenced in one tissue tends to determine its taking place in others in contact with it.

As a connecting link between changes resembling those just adduced, and those which occur in living organized bodies, may be mentioned the well-known fact, that many fruits gathered long before their living connection with the root would have naturally ceased, notwithstanding undergo those changes which render them ripe, or in other words, bring them to a state of maturity. In the leaves of plants, a short time before they lose their connection with the branch, and also when they have been detached from it, a chemical change takes place, which produces the Xanthophylle or yellow colouring principle on which the hues of autumn in great measure depend. Before we can apply the principle of these changes to the assistance of our investigation of the changes effected in living bodies, it is important that the laws which regulate them should be further elucidated. The labours of some of our continental chemical brethren have already considerably advanced the subject. Without swelling this preliminary report with an analysis of what they have done, it will be sufficient for our present purpose to adduce, without attempting any chemical explanation, some of the apparently parallel phænomena to which we invite the attention of those who may be disposed to co-operate in this kind of research. As farina or starch may be converted into gum, and both farina and gum into sugar, and these into various acids, or into alcohol or æther, so it would appear that other principles may be changed according to a particular course of succession, though some of the possible links may not be always essential. The very possibility of such successive changes renders it necessary to take into consideration another element, viz., *time*; and in our inquiry into the production of different secretions, we must, besides investigating the anatomical and chemical composition of the secreting organ, and the qualities of the matter when first produced, as compared with its ultimate state, not fail to take *time* into the consideration. The first rapidly produced secretion from a mucous surface is nearly serous. Newly and rapidly formed mucus is thin and aqueous when compared with that which has been long detained upon the surface of the secreting membrane. When milk is too frequently drawn from the lactiferous glands it is thin and watery compared with that which is allowed to be longer retained. The production of pus is another example, and one in which the changes may be followed

by the eye through their whole course. When pus has been well removed from a suppurating surface its place is soon supplied by a thin and watery secretion. This afterwards becomes viscid, but without being visibly particled; it afterwards becomes manifestly particled and turbid, and ultimately thick, opaque, and cream-like. There are perhaps no secretions which are more interesting than those in which a fatty or resinous matter is produced. They may be contrasted with the production of oily matter in living vegetables, and with the conversion into adipocere in dead animal matter. The most recently produced secretion of a sebaceous follicle is nearly or quite aqueous, but it soon appears to be albuminous or caseous, and does not appear to possess any oleaginous property. This it soon after acquires when it becomes the natural unguent to the skin. When the secretion fails to escape it accumulates, and a collection of grumous fatty matter is formed. In the early embryo the situation of the adipose substance is occupied by small grains of an opake whitish substance, which appears to be rather albuminous or caseous than truly adipose. The production of cream in the lactiferous glands, when the milk is allowed to be well formed, appears to be another physiological instance. The next is of a pathological character. It is well known that in or near the ovaries it occasionally happens that encysted masses are found, containing fat, bone, teeth, and hair. Although the whole of these materials are not necessarily found in the same specimen, fatty matter appears to be invariably present. These extraordinary productions are generally referred to conception, and are indisputably closely allied to, if not identical with, it. Now in the natural ovum but a comparatively small portion of fatty matter exists, and certainly none in the situation in which the peculiar fatty matter which forms so large a portion of these encysted formations is met with. It would therefore appear that when growth as well as development has been suspended in these irregular efforts of the nisus formativus, there commences a conversion of the collected elements into a fatty substance by the introduction of a new chemical arrangement of the elements. Even this change is progressive, and it would appear that the fatty matter when formed is susceptible of further change; for in some of these collections the fatty matter appears clean, nearly white and uniform; in others it approaches the character of cholesterine; and in one instance we have met with it, having a bright yellow colour, and a strong, penetrating, empyreumatic or bituminous odour, bearing considerable resemblance to an unctuous yellow substance, found as a mineral production in Scotland some few years since, and placed in the possession of

Professor Jameson. Next to these changes taking place in the living body, yet probably, except in the case of fœtal fat, beyond the limits of organization, it may perhaps be allowable to place the pathological degeneration of some tissues into fat. The muscles of the limbs and the contractile fibrous coat of an enlarged and thickened bladder have been found converted into this substance. The most frequent, as well as the most remarkable of these fatty degenerations is the production of fat livers, which has attracted the special notice of some foreign pathologists. It is comparatively rare in this country, and but few very well marked instances have been met with amongst many hundred inspections performed during several years at Guy's Hospital; yet what have appeared to be approaches to it have not been very rare. This degeneration essentially belongs to the acini, which are generally, if not invariably, enlarged in size, paler, and less supplied with blood than in the healthy state, and have nearly or wholly lost their power of secreting bile. In the advanced cases, the specific gravity of the liver becomes less than that of water, and fatty matter forms by far the largest part of its composition, whilst in other cases in which this degeneration has taken place fat has only formed a small per centage. Now it is not very uncommon to find in cachetic patients, who have long been unable to take exercise, a considerably enlarged liver, dependent on the great hypertrophy of the acini, which, though wanting the essential characteristics of the fatty degeneration, are paler and more homogeneous than in the healthy liver, and have more or less lost the power of producing bile. It is perhaps not too wild a speculation to imagine, that in this impaired condition of the organ it may not be able to resist the tendency to those changes which inorganized animal matter undergoes when placed in circumstances favourable to their production. This leads us to another remark, applicable to other cases, and which seems to reconcile the speculations which we have allowed ourselves to offer with facts which will doubtless be readily admitted.

The different tissues, while they retain their healthy condition unimpaired, resist these common tendencies more or less forcibly, and apparently in each in a peculiar manner, and they are consequently enabled to maintain their own peculiar composition, notwithstanding the incessant molecular changes effected by nutrition; and where they happen to be secreting organs, the same uniformity is preserved in their products. But when they are impaired by disease or accident this isolating faculty is injured or lost. Thus in the experiments of Majendie, Fœdera, Segellas, Meyer, Tiedemann and Gmelin, and others, with refer-

ence to absorption, transudation, and imbibition, we meet with some results, obtained in the injured bodies of animals employed in these inquiries, which are not perfectly similar to those phænomena which may be observed when the corresponding organs of perfectly healthy and vigorous animals are concerned; fluids possessing various properties being seen to enter into the circulation, and to penetrate membranous and other textures in the experiments alluded to, whilst in the latter case they meet with impassable barriers. The diffusion of a diseased process, as in the instances of the degeneration of structures in the vicinity of malignant tumours, alluded to at page 10, does not appear to take place until these structures have been impaired by inflammation, when the new product to which this disturbance of function gives rise presents the character possessed by the adventitious structure. This view of the case, if correct, tends to strengthen our opinion, that inflammation is not to be regarded, as some have supposed, as a condition of exalted vitality, but quite the reverse. It also directs us, in our inquiry after the chemical attributes of vitality, to fix upon the precise attractions which it is engaged in counteracting.

THOS. HODGKIN, M.D., &c., &c.

Report from the Committee for inquiring into the Analysis of the Glands, &c., of the Human Body. By G. O. Rees, M.D., F.G.S.

Part II.

There are but few analyses recorded of the glands of animals, or of those solid products of disease which it seems desirable to submit to the searching powers of chemistry. If we refer to the observations of Berzelius, and the various analyses of Frommherz and Gugert, performed on some of the glands from the human subject, we cannot but be struck with the great difficulties which must attend any attempt at quantitative examination by the method of analysis adopted by these chemists. It is my intention to propose a form for the analysis of the various solid parts of the human frame, and so to establish a settled method in proceeding, which shall enable us to make such comparative experiments as may assist in the detection of any aberration from the healthy condition of any single organ.

A diseased condition of an animal part must consist either in the increased or decreased proportion or absence of some one of its constituent parts, or in the addition of some adventitious principle to its component elements. As both these conditions are frequently present (since the latter implies the existence of the first), it becomes of the greatest importance to be able to detect not only the existence of any new principle in the diseased part, but likewise the quantity of each constituent which is present in health, as by that means we are enabled to ascertain what normal constituents or portions of a constituent of the gland have been displaced to make room for the morbid matter which has been deposited. For this purpose we must have recourse to quantitative analysis, and I hope to be able to show that most of those difficulties are surmountable which appear to have deterred many from prosecuting this line of investigation. I have been much encouraged to hope for a useful result from this inquiry, by considering how many valuable indications of disease have been afforded us by the most simple uses of chemistry when applied to the urine: here we observe that ascertaining the proportion of water alone has given rise to much philosophical reasoning and valuable information, as regards the economy of the organismus; and a steady and indefatigable inquiry into the existence of albumen in the urine led Dr. Bright to a discovery, the importance of which is every day becoming more

obvious, and which has deservedly stamped him as one of the most ingenious observers in the medical profession.

I think it is hardly too much to hope that, could we procure a sufficient number of experiments on the proportion of water only in various glands, or in a single gland in any one disease as compared with the healthy condition, we might be able to arrive at some valuable information in the history of such affection.

The great difficulty in the prosecution of this inquiry lies in the obstacles that are so frequently occurring to the performance of post-mortem examinations, and the time which is allowed to elapse before the inspection is made; these difficulties, however, are lessening every day, and at most public hospitals we have ample opportunities for research.

The analysis of the blood and the secretion of glands has been a subject of interest and attention to the chemical world, and I have long wondered how it has happened that the methods of analysis applied to such matters have never been used to investigate the chemical nature of the solid parts of animals. It is this which I would propose, viz. the adaptation of those rules of analysis used for the examination of the blood to the investigation of the chemical nature of the glands of the human body. When we look to the analyses of animal fluids, as performed by the best chemists, we perceive that the constituents of such matters (at least those which are purely animal) are considered as determined by their solubility or insolubility in certain menstrua; the principal of these being water, alcohol, and æther. Thus we have a principle, considered as a distinct component of the blood, which is sometimes called osmazome; this is noted by quantity in healthy blood, and the result used for comparison; but let us consider its right to the character of a distinct principle, and we shall at once be constrained to allow that such character is entirely the result of a single property, viz. its solubility or insolubility in certain menstrua, these being used to separate any one of the components of the fluid from the rest. That any of these component parts may be compounded in themselves is very easily credible and as easily proved; thus the extractive matter of urine, frequently estimated as though it were a proximate element, is divisible, when subjected to further chemical reactions, into three separate forms of extractive. I merely quote this instance to show how impossible it is (in most cases) to look upon animal analysis in any other light than as a means of performing comparative experiments. There is one very important step needed, however, before we can proceed to examine the glands of the body on the same system that is used

for the blood and secretions; this consists in fixing some determinate character to the extractives we may separate by means of the various menstrua employed in the analysis, for we require experiments to show that alcohol will extract the same matters from any gland that it is capable of separating from the dried blood; indeed it is not impossible that every gland may have a set of extractives peculiar to itself. For this inquiry I would especially beg attention and co-operation, as it is a subject so extensive as to require a multitude of experiments before we can expect any results applicable to pathology.

It is to a chemical knowledge of the nature of the various extractives that we must become indebted for ascertaining any of those divarications from health which it will be the ultimate object of the inquiry to detect: such a knowledge must be the result of careful examinations and comparisons of several healthy specimens of each organ; so that we may be able to decide upon the true nature of any of these animal extractives. A standard of comparison for the quantitative analysis of diseased organs will require several quantitative experiments on each organ in health before the normal average can be determined. I will now proceed to show the practicability of a method of analysis, which, if adopted, I do not doubt will develope some valuable results to the profession. I have before stated, that in the analysis of the blood we use three principal fluids as separators of its constituents, viz. æther, alcohol, and water. It is on the dividing action of these fluids that I wish to proceed, and should propose that the analysis thus divide the substance submitted into four parts, viz. 1st. That which is soluble in æther. 2nd. That which is soluble in water only. 3rd. That which is soluble in water and alcohol. 4th. That which is *insoluble* in all the three menstrua. This method, which is used for the blood, will be found very applicable to solid matters, which, as regards analysis, may be considered as partially dried serum. I do not wish it to be understood from this that we must expect to separate the same principles from each gland as we do from blood, by means of the same menstrua, but merely that the same process may be used; for, as I have before stated, each gland may have extractives peculiar to itself; but having partially divided the constituents of the gland by means of the same menstrua that are used for the analysis of the serum, we are better able to examine their properties, and, moreover, have the valuable advantage of forming comparisons with the constituents of serum, some of which will undoubtedly be present in every organized substance of the human frame. I will now notice in order the different divisions of our analysis, as formed by the

solubility or insolubility of animal constituents in æther, water, and alcohol.

1st. Those constituents of animal matter which are soluble in æther.

Under this head we have the various fatty matters of the glands for consideration; and, if this plan of analysis be extended to the products of disease in the various parts of the body, we shall find much matter of interest in the examination of this extract. The various modifications of fat, as occurring in diseased parts, and their secretions, have scarcely procured the attention they deserve from chemists. The peculiar nature of the fatty matters of the blood affords every facility for an easy passage into several varieties of that substance, and we find a series of very interesting changes in the secretions, excretions, morbid secretions, and growths of the human body. Thus cholesterine, which was once supposed to be the result of the secreting action of the liver, has been found in the fluid of hydrocele, in ovarian tumours, &c. When the nature of the fatty matter of blood is known, it ceases to be a subject of surprise that cholesterine is so generally distributed, for the chemical reactions of the crystalline fat of the blood are almost identical with those procured from cholesterine, and probably but very slight means are needed for the reduction of one to the other. I may mention that cholesterine differs from the crystalline fatty matter of the blood in affording an ash having an alkaline reaction on test paper, whereas the crystalline fat yields an acid ash owing to the presence of phosphorus. In every other reaction, however, these substances are so much alike that it is almost impossible to distinguish them. I find that the alkaline ashes of cholesterine are in about the proportion of 2·5 per cent., containing an alkaline, carbonate, and muriate, traces of sulphate and phosphate, and also phosphate and carbonate of lime.

The other forms of fatty matter met with in animal analysis are adipocere and common animal fat. I now come to the second division of our analysis, viz.:

2nd. Those constituents of animal matter which are soluble in water only.

In the analysis of the blood, the extractive procured as soluble in water only consists apparently of albumen in combination with soda. The extractive procured by similar treatment of any of the glands of the body will require examination, and constitute an important part of our inquiry, as it probably may be of different nature in each gland. This extractive, as procured from blood, is precipitable by acetic acid, the precipitate consisting of albumen in a gelatinous form.

3rd. Those constituents of animal matter which are soluble in water and alcohol.

The extractive procured from blood, as soluble in water and alcohol, is that to which the name of osmazome has been given by chemists; it is called *extrait de viande* by the French, as procured from the blood it is precipitable of a brown colour by infusion of galls; the precipitate thrown down by subacetate (or di-acetate) of lead is soluble in an excess of that reagent. These reactions are sufficient to guide us in making our comparative experiments.

4th. Lastly, we shall notice those constituents of animal matter which are insoluble in all the three menstrua employed in our analysis.

This residuum, as procured from the serum of blood, consists of albumen, but is of different constitution in the various glands and solid parts of the body; thus the more firm portions of each gland are made up of the insoluble structure of blood vessels and absorbents, with more or less of the albuminous net work of the cellular tissue, making up the parenchyma. It will be necessary for us to set down these various parts under a single head, as we do not possess any means of separation; still, although we are thus prevented from ascertaining any deficiency or excess in any single one of these insoluble constituents of the gland, yet we shall very probably be able, by comparison of the three together with the similar combination in healthy specimens, to arrive at data which may be useful to us.

Having now glanced at the probable contents of each extractive, I shall proceed to describe particularly each step in the prosecution of the analysis.

Directions for the analysis of solid animal matters.

A certain weight of the animal substance, sliced as minutely as convenient for manipulation, is to be carefully dried over a water-bath till it ceases to lose weight, the dry residuum being weighed; the loss experienced is to be noticed in the analysis as "water." Water.

The dried animal matter is now to be digested, with three times its bulk of rectified æther, for four or five hours in a closed test tube, the mixture being shaken frequently. This æther being poured off, a second portion is to be added, and allowed to digest on the animal matter in a like manner. We thus procure an æthereal solution A, and a residuum B.

A. The æthereal solution being allowed to evaporate to dryness, the fatty matters deposited are to be dried over a water bath, Fats. and their weight ascertained.

B. Water, at a temperature of 212°, and equalling six times the

bulk of the solid matter, is to be digested on the residuum for half an hour; this liquor being poured off, a second portion is to be added and similarly digested; this mixture is now to be thrown on a filter, and washed with boiling distilled water, until the percolating fluid ceases to afford a precipitation by a solution of nitrate of silver*. The first and second digested liquors, and the washings being added together, are now to be evaporated over a water bath till dry, and till no more weight can be lost by further use of the bath heat.

We thus procure an aqueous extract C, and leave on the filter an insoluble residue D. The weight of extract C must be taken.

Insoluble albuminous matter and vascular tissue.

D. The residue on the filter is now to be dried, its weight ascertained, and set down in the analysis as insoluble albuminous matter and vascular tissue.

C. The aqueous extract is next to be acted upon by digestion for a quarter of an hour, with four times its bulk of alcohol, at a boiling heat. The solution so formed being poured off, a second portion of alcohol is to be similarly digested, the mixture then thrown on a filter, and the liquor allowed to percolate. The two portions of fluid being added together are next to be evaporated to dryness over the water bath. We thus procure an alcoholic extract E, and leave on the filter an extractive F, which is not soluble in alcohol. The former is to be dried and weighed, and estimated as "extractive soluble in alcohol and water," and the latter, similarly prepared, is to be estimated as "extractive soluble in water only." The added weights of these two extractives should equal that of the extract C†.

Extractive soluble in alcohol and water.

Extractive soluble in water only.

In conclusion, I must express my regret at having been prevented by a variety of circumstances from bringing forward analyses of glands, either healthy or affected by some well-recognized degeneration. I have, I hope, made some amends by proposing a set form of examination, by the adoption of which, analyses, though executed by a variety of persons, may be made serviceable as comparative experiments in any single inquiry. The adoption of some such form is quite necessary before the objects of the Association can be answered; for they have proposed a subject far too extensive to be developed, otherwise than by a multitude of experimenters, all working by the same rule of analysis.

* No washings are to be commenced until all the liquor of digestion has first passed through the filter.

N. B. The silver test can be used on a single drop of the filtering fluid.

† These extractives, as also the insoluble albuminous tissue, must be incinerated, the ashes examined, and noticed in the analysis.

Second Report of the London Sub-Committee of the British Association Medical Section, on the Motions and Sounds of the Heart.

The Committee appointed in London by the British Association for the Advancement of Science, to investigate the Motions and Sounds of the Heart, have the honor to lay before this meeting a short account of some investigations of the *abnormal sounds* of the heart and arteries in which they have been recently occupied.

Before describing these, the Committee would remark, that although their last inquiries have not been specially directed to that subject, yet they have had many opportunities of verifying the conclusions on the *natural* sounds as presented in their report of last year; and these conclusions not having been since shaken by any experiment or rational objection, it may be considered as fairly established, that the first or systolic sound of the heart is *essentially* caused by the sudden and forcible tightening of the muscular fibres of the ventricles when they contract; and that the second sound, which accompanies the diastole of the ventricles, depends solely on the reaction of the arterial columns of blood on the semilunar valves at the arterial orifices. It further appears that the first sound may be increased by an additional sound of impulsion against the walls of the chest, under certain circumstances of posture, of increased action of the heart, and of certain stages of the respiratory movements. It is also obvious that the character of the first sound may in some measure depend on the closure of the auriculo-ventricular valves, and on the quantity of blood; inasmuch as these determine the nature and time of the resistance against which the muscular fibres of the ventricles tighten. So, likewise, the vigour of the ventricular systole, the quantity of blood propelled by it, the sudden and complete character of the diastole, the fulness of the arterial trunks, as well as the perfect, mobile, and membranous condition of the semilunar valves,—will determine the character and loudness of the second sound. An experimental illustration of the effect of one of these conditions was observed by the Committee in the great diminution of the second sound by the free division of the carotid artery, which would greatly diminish the arterial tension.

As additional illustrations of the production of a sound, like that of the heart, by muscular contraction, the Committee have noticed that which accompanies the action of the panniculus carnosus of the ass during life, and the quivering contraction

of various muscles immediately after death. The sound produced in the latter case, in nature and frequency, closely resembled the first sound of the heart of the fœtus, or of small animals.

In investigating the morbid sounds of the heart, the attention of the Committee has been chiefly directed to the causes of those remarkable and various phenomena called murmurs, which are either added to, or supersede the natural sounds of the heart, and which were happily compared by *Laennec* to the familiar noises of blowing, filing, rasping, sawing, purring, cooing, &c. This inquiry consists of two parts: 1. What is the essential physical cause of the phenomena in question? and 2. How does the apparatus of the circulation develope this cause in the various instances in which these phenomena are known to occur? To the first of these questions the experiments of the Committee supply what they trust will be deemed a satisfactory answer. The second is to be fully answered by extensive clinical and pathological observation, rather than by direct experiment; and although a few physiological illustrations will be cited to this point, yet the Committee do not profess to do more than to open this inquiry to all those who have the means of pursuing it.

Experiments on the production of sound by the motion of water through tubes.

A Caoutchouc tube, eighteen inches long, and three-eighths of an inch in diameter, was attached to the stop-cock of a reservoir in which there was water to the depth of eight or ten inches.

When the water flowed unimpeded through this tube (all the air being first expelled,* and the lower end of the tube kept under water in a vessel below) no sound was heard; but on pressing any part of the tube so as to diminish its caliber, a blowing sound was heard, at and below the point of pressure, and this sound became louder and more whizzing as the pressure was increased. The loudest sounds were obtained at the lowest end of the tube, where they were sometimes quite musical; and by increasing the pressure or the current at regular intervals, a periodic increase and raising of the sound were produced, closely resembling the murmur sometimes heard in the neck, to which the French have given the name of "*bruit de diable.*"

A pin being stuck transversely through the tube, a slight blowing was heard; which was made louder on substituting for the pin a bit of split goose-quill. A stronger blowing was produced by a double thread across the diameter of the tube, especially when

* As long as any air remains in the tube, a loud crepitation accompanies the current.

the thread was rather loose; and a still louder and shriller sound ensued when a knot of string was fastened to the thread.

The same tube being adapted to the stop-cock of a water-supply pipe, through which the current could be left to pass with great force, it was found possible to imitate every variety of blowing, whizzing, and musical murmurs, by varying the pressure on, or impediment in, the tube, and by altering the force of the current. When the current was strong, the least impediment caused a murmur; but with weaker currents, greater obstructions became necessary for the same effect. A partial obstruction, which with a weak current gave a blowing sound, produced, with a stronger current, one of a more whizzing character. Grating or rasping sounds were best obtained by the effect of a strong current on a knotted thread across the diameter of the tube. The musical or uniform sounds resulted from a moderately strong current through a considerable impediment: increasing the force of the current, or the degree of obstruction, rendered the sound whizzing and imperfect; diminishing the current or the obstruction, converted it into a simple blowing. When a sound was of an appreciable pitch, its note was high in proportion to the force of the current and the amount of the obstruction; a fine forcible stream producing the highest note. Sometimes, however, with a strong current, a loud trumpet note would be set up, which was not altered in pitch, but only in force, by changing the strength of the current. This kind of note produced vibrations of the tube below the impediment, perceptible to sight and touch, and the length of this portion of the tube seemed to affect the character of the note. This phenomenon precisely represented the purring sound and tremor sometimes perceptible in the heart and arteries. Musical sounds of a more variable character, like the cooing of a dove, the humming of an insect, or the whistling of wind, were produced with a weak current passing through a tube much obstructed. The pressure of a column of water only two or three inches high, was sufficient to give acute whistling notes, which were sustained, although varying, even when the water that passed only fell in drops.

Bending the tube to an angle produced a murmur, but no sound resulted from any curve that did not infringe on the caliber of the tube. A circular constriction by a thread drawn round the tube caused a murmur, which was blowing or whizzing according to the force of the current.

When the tube with a weak current was pressed on at two points, the murmur was heard at the point where the pressure was greatest; and by increasing the pressure at one point the pressure was stopped at the other. When the current was strong,

it was easy by a pretty equal pressure to cause a murmur at both points.

With a stout Caoutchouc tube, two feet long and one inch in internal diameter, the same results were obtained, but in a more remarkable degree, in consequence of the increased size of the tube. When the current was strong and the pressure on the tube considerable, sounds were produced loud enough to be heard without applying the stethoscope or the ear; and the vibrations of the tube below the obstruction were so strong that they threw the water in little jets from the outside of the tube.

In making this experiment, the pressure of the water suddenly distended a portion of the tube into a globe about three inches in diameter, constituting a good imitation of a circumscribed true aneurism. As long as the force of the current was sufficient to keep the walls of the dilated portion tense, no sound was heard in them; but when these walls became flaccid, the passing current caused a kind of fremitus in them. Pressure on the dilatation, or bending the tube so as to form an angle at this point, also sometimes occasioned a murmur.

A globular India-rubber bottle, three inches in diameter, being adapted to an aperture in the side of a tube half an inch in diameter, so as to form an elastic sac communicating with it, a current was directed through it and all the air expelled. The same was done with a tube three-eighths of an inch in diameter, and a bottle of an inch and a half. In some positions of the tube, the current in passing the lateral sac caused a fremitus; but in others, as when the tube was straight, there was no sound. A sudden increase of current, or the removal of external pressure from the sac, occasioned a whizzing by the entry of water into the sac. Independently of the current, sudden forcible pressure caused a whizzing with the expulsion of the fluid, and a similar whizzing attended the rapid reflux into the sac, on the removal of the pressure.

Some of these experiments were repeated with water, rendered somewhat viscid with size. The results differed only in requiring a stronger force of current to produce the same effect.

Remarks and conclusions.

From all these results, it is sufficiently plain that a certain resistance or impediment to a liquid current is the essential physical cause of all murmurs produced by the motion of fluids in tubes. That any condition of the walls of the tube beyond the impeding point is not, as it has been supposed, essential to the production of these sounds, is proved by the fact that they may be produced by a partial obstruction at the terminal orifice of

the tube, or at the mouth of a gum elastic bottle, where there is no tube or wall beyond to cause them: usually, this is the situation where they can be most readily produced, because here the current has acquired its greatest momentum, and finds a free exit beyond the obstructing point. The more flaccid state of the portion of a tube beyond a partially obstructed point is a necessary effect of the scantier supply of water beyond the impediment. It is therefore a necessary concomitant of the obstruction and its sound, but is not the cause of the sound. When, however, the sound occasioned by the obstruction is strong, its vibrations may be communicated to the whole contents and walls of the tube beyond, which will then vibrate *in system* with it, and be capable of modifying its note, just as the tube of a reed instrument affects the note which is exclusively *generated* in the reed. On the other hand, when the sound generated in the obstruction is weak and varying, the condition of the tube or walls beyond it will not affect it.

In short, the laws of the production of sound by liquids so nearly resemble those which regulate the same phenomenon in air, that illustrations for the one may be taken for the other.

It may be proper to advert to an objection to this view, that a murmur is sometimes caused where there is no impediment to the course of a liquid, as when it passes suddenly from a small into a large tube, or into a sac. Now it is not true that in such a case there is no impediment, for the liquid in the large tube or sac, having less velocity, must in itself be an impediment. Besides this, the course of the smaller swift current becomes changed by spreading into the larger channel; and instead of running smoothly parallel to the tube, now strikes its walls at an angle, causing a series of impulses and resistances, which, if forcible and rapid enough, constitute the vibrations of sound. It may be remarked, however, that this modification of a moving current is not so constantly attended with the production of sound as the direct obstacle presented by a narrowing of or projection into the caliber of the tube. A current issuing from a tube or orifice into a larger vessel or sac, is also capable of producing a sound by impinging against an opposite surface.

Experiments on the production of murmurs in the living body.

About two inches of the length of the common carotid artery of a young ass was laid bare. Different degrees of pressure, either by the stethoscope or by a probe passed under it, occasioned a variety of murmurs, blowing, sawing, filing, and musical cooing at each pulse. When the stethoscope was merely placed

in contact, without pressure, no murmur was heard; but when the heart acted strongly, a simple impulse and sound.

The artery was scratched for a few seconds with the point of a scalpel; it gradually became sensibly smaller for the length of half an inch about that point. A strong solution of salt being applied, the contraction increased, but it was still of a gradual and tapering kind, and the stethoscope could detect no murmur in it; but very slight pressure on it caused a whizzing. The pulse at this contracted portion was felt to be much harder and sharper than above or below it.

A small incision being made into the artery, a jet of blood issued, and a whizzing, sometimes in pulses, sometimes continuous like the *bruit de diable*, was heard beyond the orifice, but not at the portion of the artery nearest to the heart, the sound being, as usual, carried in the direction of the current. The incision being made larger, the blood spouted to the distance of more than six feet, and the animal died in ten minutes after this last incision; the beats of the heart were frequent, short, and pretty loud, but without a second sound, and to the last without a murmur. They continued for nearly two minutes after the respiration and consciousness had ceased, becoming gradually slower.

The Committee repeated the observation that has often been made before, that a murmur can easily be produced by pressure on the subclavian, carotid, or femoral artery of the human subject. This murmur is generally of a grating or filing character, and is prolonged in proportion to the degree of pressure.

Whilst making the observations on the carotids, they found that a continuous murmur of very remarkable and variable characters could be produced by pressure on the jugular veins, especially in the angle formed by the sterno-mastoid muscle with the clavicle. The most common sound thus produced was like the humming of a gnat or fly; but occasionally it resembled the whistling of the wind, the singing of a kettle, the cooing of a dove, and sometimes it was perfectly what the French have called the "*bruit de diable.*" Dr. Ogier Ward of Birmingham had previously come to the conclusion that this sound is produced in the jugular veins, and the observations of the Committee confirm this inference: but they do not agree with this physician in the opinion, which he adopts from MM. Andral and Bouillaud, that the presence of this sound denotes a chlorotic state of the system, for which steel is indicated, or that it is essentially a morbid symptom at all. It may be produced in the healthiest subjects by moderate pressure applied to the lower part of the jugular veins, and is then found to be modified by various cir-

cumstances which can only affect the venous current. Thus it may be arrested or diminished by pressure on the vein above, by the horizontal posture or hanging down the head, and by forced efforts to expire with the glottis closed. It may be restored in increased degree by suddenly desisting from any of these acts or circumstances. The occasional pulsatory or remittent character of this sound seems to depend on the momentary increase of pressure caused by each pulse of the neighbouring artery; and when, as sometimes happens, these pulses are attended with a whizzing, this is in a measure incorporated with the venous sound, and increases the periodic swell. The size and downward current of the jugular veins peculiarly adapt them for the production of sound, but probably sounds may be produced in most other large veins when circumstances accelerate the current through them. The Committee have detected an obscure murmur in some of the large superficial veins of the arm and thigh. This murmur is not in pulses, and is to be distinguished from muscular sounds by its being confined to the situation of the veins, and its being immediately arrested by pressure on the vein. Occasionally a pretty loud murmur or fremitus is to be heard on either side of the upper portion of the sternum, which, from its resemblance in character to the venous sounds, may be supposed to have its seat in the large venous trunks that lie underneath.

Although it appears from these facts that the venous sounds are not necessarily signs of disease, yet the circumstance proved by the Committee, that water is thrown into sonorous vibrations more readily than a fluid of a more glutinous character, renders it probable that these and other sounds depending on the motion of liquids in the apparatus of the circulation may be more easily produced where the blood is thin and deficient in quantity; and under these circumstances they may occur in the neck from the mere pressure of the muscles on the jugular veins.

The Committee had planned several experiments for the further elucidation of the second part of the inquiry, By what changes, functional and structural, does the apparatus of the circulation develope the physical causes of the abnormal murmurs and sounds in the various instances in which they are known to occur? This part of the inquiry, so important for the elucidation of several obscure points in pathology, diagnosis and practice, the Committee propose to resume, if the Association should think proper to recommend them to continue their labours.

Signed Charles J. B. Williams, M.D., F.R.S.
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On the present state of our knowledge in regard to Dimorphous Bodies. By Prof. Johnston.

The subject of the following Report is one in regard to which our knowledge is yet in its infancy. It has arrived, however, at that state in which a detailed exposition and critical examination of all the facts hitherto observed, is likely to lead to new inquiries, to call new observers into the field, and thus more rapidly to dissipate the obscurity with which it is invested. It will not be uninteresting also in after years to look back upon the facts actually established, the views entertained, and the speculations hazarded at the present time,—to mark how far the phenomena were rightly interpreted,—what glimmerings of truth were mingled with the early speculations,—at what rate this department of knowledge had subsequently advanced, and how far this advance had been promoted or retarded by the hypothetical views of its first cultivators *.

I.

1. When the forms and dimensions of crystallized bodies began to be accurately observed and recorded, it was soon recognized that these might be classed among the most distinct and specific characters which solid bodies possessed. Observation seemed at first to show that each substance, simple and

* How much the progress of science depends on the mode in which phenomena are interpreted by the first observers is strikingly illustrated in the case of certain experiments of Robert Boyle. He observed that when copper, lead, iron, and tin were heated to redness in the air, a portion of calx was formed, and there was a constant and decided increase of weight.—(Experiments to make Fire and Flame ponderable. London, 1673.) This experiment he repeated with lead and tin in glass vessels hermetically sealed, and found still an increase of weight, but observed further, that when "*the sealed neck of the retort was broken off, the external air rushed in with a noise.*"—(Additional experiments, No. V., and a discovery of the perviousness of glass to ponderable parts of flame, Exp. III.) From this he reasoned correctly, that in calcination the metal lost nothing by drying up, as was generally supposed, or that if it did, "by this operation it gained more weight than it lost."—(Coroll. II.) But this increase of weight he attributed to the fixation of heat, stating it as "plain that igneous particles were trajected through the glass," and that "enough of them to be manifestly ponderable did permanently adhere." Had he weighed his sealed retort before he broke it open, he must have concluded that the metal had increased in weight at the expense of the inclosed air. He stood in fact on the very brink of the pneumatic chemistry of Priestley; he had in his hand the key to the great discovery of Lavoisier. How nearly were those philosophers anticipated by a whole century, and the long interregnum of Phlogiston prevented! On what small oversights do great events in the history of science as of nations depend!

compound, assumed, on crystallizing, a form peculiar to itself, and that this form constituted an unfailing specific character,—(Haüy.) Crystals belonging to the regular system presented the only apparent exceptions.

2. After a time, however, the generality of this conclusion was further narrowed by the doctrine of isomorphism, which showed that form alone, even when not tessular, was insufficient in many cases to determine the chemical constitution of a body*. Still, in these new exceptions, the form indicated the nature and constitution of a substance within certain limits, that it was a member of this or that isomorphous group, elevating crystalline dimensions in such instances from the rank of a specific to that of a generic character. Even this place, however, they did not long retain undisturbed.

3. Founded on the principle that the molecules of crystalline bodies have themselves a regular crystalline form, the doctrine of isomorphism hitherto recognised, that for each substance, simple and compound, this form was one and invariable; though not necessarily a specific that it was a *constant* character.

4. The earliest measurements of artificial crystals had been made on such as were formed in ordinary circumstances of temperature and by the most usual methods of manipulation. Occasionally, however, crystals formed at higher temperatures or under peculiar circumstances attracted attention; and in certain cases these new crystals were found to differ in form or dimensions from the ordinary form of the same substance, to such an extent that they could not be derived from each other by the ordinary laws of crystallization. Thus sulphur crystallized from fusion differs in form from the natural crystals and from those deposited from solutions of sulphur†. And as the resources or results of analytical chemistry were multiplied so as to place beyond doubt the chemical identity of different specimens, the examples of such differences gradually increased in number. Natural substances also were met with, crystallized under circumstances not well understood and generally beyond our imitation, which, though shown to agree in chemical constitution, yet differed wholly in form. Graphite and the diamond, both forms of pure carbon;—arragonite, and calc spar, both pure carbonate of lime, are groups of this kind.

5. To mark the singular character possessed by these bodies, they have been distinguished by the term *dimorphous*, and the abstract property by that of *dimorphism*.

* Mitscherlich, *An. de Chim. et de Phys.*, XIV. p. 172.

† In bisulphuret of carbon, or in quadri (?) sulphuret of hydrogen.

6. It appears, therefore, that the crystalline form of a body is not only not a specific character, but that it is not even a *constant* character. It might also appear at first sight that this new result of observation would materially weaken the evidence in favour of isomorphism; that though two bodies (A and B) do assume the same form, or replace each other in *certain* circumstances, yet since one of them (A) is capable of assuming two incompatible forms, they may not in *all* circumstances either assume the same form or be capable of mutual replacement.

7. A further observation, however, though it does not obviate entirely, as we shall afterwards have occasion to remark, the necessity of attending to this argument, yet establishes a beautiful connection between dimorphous and isomorphous bodies, and points to some more general law, probably of molecular arrangement, by which both classes of phenomena are regulated and linked together. Certain groups of isomorphous bodies have been met with, each individual of which groups is dimorphous or capable of assuming two incompatible forms (A and B), yet in their second form (B), as in their first (A), they are still isomorphous. Thus carbonate of lime and nitrate of potash are both dimorphous, and one of the forms of nitre is isomorphous with calc spar, the other with arragonite, which are the two forms of carbonate of lime. Such groups have been distinguished by the term *isodimorphous*. All the known groups of this kind will be inserted in a subsequent part of this report (16).

8. The principle of dimorphism thus recognised, is one of great interest in the present state of chemical physics. Connected on the one hand with the crystalline doctrine of isomorphism, and on the other, as we shall hereafter see, with the chemical doctrine of isomerism, it may be regarded as standing between the two, and as likely to throw light on the cause of both.

9. The case of dimorphism, which was earliest known to chemists and mineralogists, is presented by carbonate of lime in the two incompatible forms of arragonite and calc spar. Stromeyer attempted to account for the difference between these two minerals by showing that arragonite always contained carbonate of strontian to the amount of from $\frac{1}{2}$ to 4 per cent., and from $\frac{1}{5}$ to $\frac{1}{2}$ per cent. of water*; and the presence of these sub-

* *Untersuchung über die Mischung der Mineralkörper und anderer damit verwandten Substanzen.* Göttingen, 1821. In this work are ten analyses of arragonites, undertaken in confirmation of his previously published opinion, which had been controverted. Great credit was due to Stromeyer for his beautiful analyses, but there is now no reason to believe that either strontia or water are *necessary* constituents of arragonite.

stances was considered by many chemists to afford a plausible explanation of what was then regarded as a very singular anomaly. A few years after the publication of this opinion, however, Mitscherlich observed a similar difference between the form of sulphur crystallized from fusion, and that in which it occurs in the mineral kingdom*; and as in this case it was easy to prove the absence of any foreign body, it became necessary to attribute the difference to some other cause than that advanced by Stromeyer, to explain the production of arragonite. The prosecution of the inquiry soon put into the hands of Mitscherlich other examples, and since that period scarcely a year has passed without adding some new facts to our growing knowledge.

10. The following table contains a list of all the substances hitherto described as dimorphous, and it embodies nearly every thing we at present know in regard to the chemical and physical differences which the several forms of these substances present. See opposite table.

11. To this list might have been added *anatase* and *rutile*, were it not that some doubt still exists as to whether both of these minerals consist of titanic acid only. They crystallize in square prisms of different dimensions and having different cleavages. The bichromate of potash appears also to be dimorphous, crystallizing from fusion, in a form which it does not retain on cooling†. I have also obtained from a London manufacturer crystals of iodide of potassium in square prisms three-eighths of an inch ($\frac{3}{8}$ in.) in length, which are frequently deposited along with the ordinary cubical crystals from the concentrated solution. On resolution and evaporation they give only cubes. They exhibit traces of double refraction, which, however, the opacity of the crystals renders very indistinct. Mr. Brooke, to whom I have submitted them, is unable to pronounce decidedly as to their form, from the want of well-defined secondary faces. Like the capillary red oxide of copper from Cornwall, they *may* be only an aggregation of cubes. Dufrenoy‡ states that cast iron has been observed in cubes and in rhomboids, but the statement is of too uncertain a kind to be deserving of much confidence§. Among the ordinary crystals of sulphate of potash with two axes, Sir David Brewster states that he observed some six-sided prisms with only one axis of double refraction.

* Poggend. *Annalen* VII. p. 528, (1826.)

† See Table IV. p. 26.

‡ *An. de Chim. et de Phys.*, LVI. p. 198.

§ It was formerly considered that the sulphates of zinc and magnesia belonged to the group of dimorphous sulphates, but later observations of Mitscherlich have shown that the supposed second form contains only 6 atoms of water.

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TABLE I. Exhibiting a list of all the known dimorphous bodies, and the observed differences in the physical properties of the two forms of each substance. 1837.

Substance		Symbol or Formula	Crystalline Form	Form occurs.	How obtained, or where.	Density		Hardness.	Relations to Light. Opake or transparent.	Colour.	Lustre.	Refractive Power.	Relations. To Electricity.	To heat.	Solubility in 100 pts of Water.	Characteristic or Remarks.	Authorities.
Elementary Bodies.																	
Sulphur	A	S	Rt. Rh. Pr. M on M 101° 59′ *Had.*	Abundantly	Native and from solution of S in CS_2		2·05001 *Kr*	1·5 to 2·5	Transparent	Greenish yellow	Resinous	2·115 *Br.*	Non-conduct.		0		Mitscherlich, *Pog. An.*, xxiv. p. 328
—	B		Oblique Rh. Pr. of 90° 32′ *M*	Rarely	By fusing A	Same crystal fused	1·9889	?	Do. becoming opake	Do.	Do	Fused 2·148 *Br.*			0		Gmelin's *Wörterbuch*, i. p. 151
Carbon	A	C	Reg. Octohedron	Commonly	Native in diamond		3·5 to 3·55	10·0	Transparent	0	Adamantine	2·487 *Br.*	Non-conduct.		0	Common charcoal is considered by some chemists to be a third modification. That in the former the particles are minutely divided and separated appears sufficient to account for all the observed differences.	
—	B		Rhombohedral	Do.	Do. in graphite, occurs in iron furnaces	2·3285 *Kr.*	2·0891 *H.*	1· to 2·	Opake or translucent	Black by reflected	Metallic	2·44 *W.*	Conductor		0		
II. *Binary Compounds.*																	
[illegible]	A	Cu_2O	[illegible]	Mixed in Red Copper	Native		6·0	3·5 to 4	Transparent	Red	Adamantine						
—	B		Rh. of 99° 15′, 6-sid. Pr. rhomb. cleav., *Sk*	Rarely in Kupfer bluthe	Do. Saxony, Cornwall?		?	?	Do.	Do.					0	According to Brooke the fibrous red oxide of Cornwall is only an aggregation of cubes	Suckow, *Pog. An.*, 1835, p. 328
[illegible] of Copper	A	CuS or Cu_2S	Do. primary a rhomb. P on P′ 71° 30′	In Vitreous Copper	Found native		5·7	2·5 to 3·	Opake	Lead grey	Metallic						
—	B		Reg. octohedrons	Rarely	By fusion		?	?	Do.	Do.	Do.				0		Mitscherlich, Rose, *Crystal.* p. 157.
Sulphuret of Silver	A	AgS or Ag_2S	Cube in Silver glance	Commonly	Found native		7·196	2· to 2·5	Do.	Do.	Do.				0		Ibid. p. 142
—	B		[illegible]	Rarely	Do. in AgS+Cu_2S from Rudelstadt		?	?	Do.	D[illegible]					0		Ibid. p. 157, Sander, *Pog. An.*, xl. p. 313
	A	MnS	Cubes	Common in Kobellite	Native in Europe		4·014	3·5 to 4	Do.	Steel grey	Imperfect do.				0	I have inserted this as dimorphous on the authority of Del Rio; further information is very desirable.	Del Rio, *Silliman*, xxx. p. 386
	B		Rhomboid	Rarer ?	Do. in Mexico			?	Do.								
	A	FeS_2	Cubes	Abundantly	Do. in iron pyrites		4·6 to 5·031	6 to 6·5	Do.	[illegible]	Metallic						
—	B		Rt. Rh. Pr., M on M′ 106° 2′	Do.	Do. in white do.		4·678	Do.	Do.	Pale whitish yellow	D[illegible]				0	The form B generally undergoes [illegible] in the air than A	
Iodide of Mercury	A	HgI_2	Octohed. with square base	Common at ord. temp	From a saturated solution of HgI_2 in KI		5·2009 *Kr*	?	Transparent	Red					0	The yellow sometimes retains its form at 60° F., but a touch suffices to set the particles in motion.	Mitscherlich, *Pog. An.*, xxviii. p. 116
—	B		Rt. Rh. Pr. MM′ 114°	Do. at higher temp.	By heating A		?	?	Do.	Yellow							
[illegible] of Mercury	A	$HgCl_2$	Rt. Rh. Pr. MM′ 71° [illegible]	Abundantly	Crystallizing from solution in alcohol		?	?	Do.	0					?	These two forms are mutually derivable, but Mitscherlich thinks they are probably distinct. They have no relation to the forms of the biniodide.	
—	B		[illegible]	Do.	By sublimation		5·4032 *K*	?	Do.	0							
	A	[illegible]	[illegible]	Commonly	Do. [illegible]	Native	3·698 *K. D*		Cryst. transparent [illegible]	0	[illegible]				At 60° 3 pts; 212° 50	Solution of opake mass in HCl emits no light [illegible] crystallizing	H. Rose, *Pog. An.*, xxxv. p. 481
	B		Rt. Rh. Pr.	Rarely	Occurs [illegible]	[illegible]	3·729 *Hr*		Transparent like glass*	0	Splendent, glassy				At 60 1·25; 212 11·50	Solution of glassy mass gives out no light on crystallizing; the crystals are octohedrons	
															At 60 0·96; 212 [illegible]	[illegible] in mass opake. The glassy [illegible] the form B or in a *third* state	
Oxide of Antimony	A	Sb_2O_3	Do. M on M 136° 58′	Generally	Native in white antimony		5·566	2·5 to 3·0	Translucent	0	Adamantine				0		Wöhler, *Ann. de Chem.*, li. p. 201.
—	B		Reg. octohedrons	Rarely	By sublimation		?	?	Do.	0					0		Wöhler, Ibid.
III. *Compounds of 3 Elements.*																	
Carbonate of Lime	A	CaO+CO_2	Rhomb. of 105° 4′ *M.*	Abundantly	Native in calc spar	2·716 *R.*	2·721 *M.*	3·0	Do.	0	Resino vit., or pearly			No action at red heat, sp. heat = 0·2046 *N.*	0	Form and action of heat. CaC thrown down from cold solutions is calc spar; from hot arragonite	Rose, *Pog. An.*, xlii. p. 366
—	B		Rt. Rh. Pr. of 116° 16′ *Kn*	Less commonly	Do. in arragonite	2·949 *R*		3·5 to 4·0	Do.	0	Resino vit.			Decrepitates at do., sp. heat = 0·2018 *N.*	0	Do. exhibits anomalous epoptical figures; no decrepitation assumes the form [illegible] of calc spar	Erman, Berlin Trans., 1832, p. 1
Carbonate of Magnesia	A	MgO+CO_2	Rhomb. of 106° 15′	Abundantly	Native in bitter spar		2·881	3·5 to 4	Semitransparent	0	Vitreous, pearly	?	?		0	When the solution in C is evaporated to dryness the arragonitic crystals are obtained mixed with radiated groups of magnesia alba	
—	B		Rt. Rh. Pr.	Rarely	Evaporating a solution of MgC in C.		?	?	Do	0	?	?	?		0		Rose, *Pog. An.*, xlii. p. 366
Carbonate of Iron	A	FeO+CO_2	Rhomb. of 107° 0′	Commonly	Native in brown spar		3·6 to 3·821	3·5 to 4·5	Opake	Yellow-brown	Vitreous, pearly				0		
—	B		Rt. Rh. Pr. 108° 26′, 118° 0′?	Rarely	Do. in junckerite		3·815	4·	Do.	Do.					0	The dimensions of the prisms of junckerite are so different [illegible]	Dufrenoy, *Ann. de Chim. et de Phys.* June, 1834, 198
Carbonate of Lead	A	[illegible]	Rhomb. of 104° 53′?	Do.	Do. in plumbo calcite		?		Transparent	0					0		
—			Rt. Rh. Pr. of 117° 14′, *Ku.*	Commonly	Do. in white lead spar		6·46	3·0 to 3·5	Do.	0	Adamantine, resinous				0	The form of the plumbo calcite [illegible] occurs at Wanlockhead, Scotland	Johnston, Brewster's Jour. xi. p. 73
	A	KO+NO	Rt. Rh. Pr. M on M′ = 118° 52′, *Lr*	Common form	In nitre of commerce		2·6232 *Kr.*	?	Do.	0					At 60 F. 14·3, 212° F. 100	Crystals permanent. A drop of a sat. sol. gives on evap. prism cryst. and rhomb. tables of 102° 50′, which change their form when rubbed, pressed, or touched with a prismatic crystal	Mitscherlich, Levy, R. Inst. Jour. [illegible]
—	B		Rhomb. of 106° 36′ *Fm*	Rarer do	By evaporation [illegible]		?	?	Do.	0					More soluble than A		Frankenheim, *Pog. An.*, xl. p. 447
	A	PbO+CrO_3	[illegible]	Common	Native		6·004	2·5 to 3	Translucent	Hyacinth red	[illegible]				0		Brooke, Johnston, [illegible] Phil. Mag., May 1838.
—	B		Square prism	Rarer	Do		?	?	Do.	Do	Do				0		
	A	NiO+SO_3+7HO	Rt. Rh. Pr. M on M′ 91° 10′ *Bk*	Common	By evaporation at common temperatures		?	?	Do.	Green					At 60° 33 pts	In the air the rhombic effloresces more readily than the square prism, *Bk*	Mitscherlich
	B		Square prism	Rarer	Exposing A to the sun's rays or crystallizing from warm or acid solutions					Do.							
Seleniate of Zinc	A	ZnO+SeO_3+7HO	Rt. Rh. Pr.	Common	By evaporation at common temperatures		?	?	Transparent	0					0		Do.
—	B		Square prism	Rarer	Exposing A to the sun's rays, &c.		?	?	Do	0					0		Do.
Bisulphate of Potash	A	KO+SO_3+$\overline{HO+SO_3}$	Rhombic octohed. (form of sulphur) *M*	Common	By evaporation		?	?	Do.	0					At 212° 200 pts	I have inserted this substance on the authority quoted. [illegible] the quantity of water in the fused salt, which Herr Arsberattelse, 1837, p. 126, states to be the case	Mitscherlich, *Pog. An.*, xxxix. 198. See also Beudant *Chim. Phys.*, iv. 72
—	B		Ob. Rh. Pr. (form of Felspar) *M*	Rarer	By fusing A		?	?	Do.	0					?		Mitscherlich.
	A	NaO+P_2O_5+HO	Rt. Rh. Pr. of M on M′ 93° 54′	Common	By spontaneous evaporation		?	?	Do.	0					Largely soluble		Do.
—	B	or NaH P+2H	Do. of 78° 30′	Rarer	Do.		?	?	Do	0					Do.		Do.
	A	[illegible]	Reg. dodecahedron	Commonly	Found native		3·6 to 4·2	6·5 to 7·5	Transp. & translucent	Yel.-brown bl., *gros.* [illegible]	Vit., resinous			Before blow-pipe melts quietly	0	[illegible] Magnus found that grossularite (sp. gr. [illegible]) and the greenish [illegible] sp. gr. [illegible] had the same sp. gr. after being melted	Magnus, *Pog.* [illegible]
			[illegible]	Do.	Do.		[illegible] to 3·4	6·5	Do	Do.	Do.			Swells up with evolution of bubbles, *K*	0		Kobell, [illegible]
	A	[illegible]	[illegible]	Do.	Do.		3·646 *F*	4·0	Transparent	0	Vitreo-resinous			Decrepitates	0		Brooke, Ch. [illegible]
			[illegible] form of arragonite	Do.	Do.		2·7 *J*	Scratches A	Do.	0	D[illegible]			Do. much	0	The [illegible] See Mineralogy	Miller, Johnston, Phil. Mag., 1837
		[illegible]	[illegible] M on M 120°	Brooke	Found native at [illegible] Falls		6·[illegible]	2·5	Do.	*Native*, brown, yel. green					0		[illegible]

* [illegible] there must be three varieties or modifications of this [illegible] upon the [illegible], which, according to the subsequent measurement of Brooke, is incorrect.

Bk. Brooke; *Br.* Brewster; *H.* Haüy; *Gm.* [illegible]; *Hr.* Herapath; *K.* [illegible]; *Kr.* Kupffer; [illegible]; *M.* Mitscherlich; *N.* Neumann; *R. D.* Rogers and Dawson; *Sk.* Suckow; *W.*, Wollaston; *Fm.*, Frankenheim; *R.*, Rose.

If these were crystals of sulphate they would indicate a dimorphism in this salt also.—Edin. Phil. Jour., vol. i.

Other substances likely to prove dimorphous are inserted in Table III., and it is not impossible that some of those forms now considered *pseudo-morphic,* may hereafter appear to be true cases of dimorphism.

Several observations suggest themselves on a glance at this table.

12. The number of substances contained in it, and of which the dimorphism has been discovered in so short a time, renders it very doubtful whether the crystalline form assumed by *any* given substance is one only and invariable.

13. The several forms of the same substance possess different physical properties,—different colour, hardness, density, or relations to heat and light. This is true of every pair of dimorphous bodies in the table, yet in all of them the chemical relations remain unchanged. The only trace of an exception, yet observed, is in the different solubilities of the two forms of arsenious acid and in the different behaviour of garnet and vesuvian before the blow-pipe. These chemical differences, however, are too obscure to demand much attention in this place; were they distinct and well-defined, the compounds which exhibit them, should be removed from the class of simply dimorphous to that of isomeric bodies*.

It appears, therefore, that dimorphous bodies exhibit in their several forms physical differences only, the chemical relations remaining unchanged. To this remarkable characteristic of such bodies we shall have occasion to advert when we come to inquire into the cause of dimorphism and its connection with isomerism.

In dimorphous compounds which element is dimorphous.

14. In the relation between the first and second forms of several of the groups in the Table, a striking analogy presents itself. In the carbonates of lime, of magnesia, of lead, and of iron, and in the nitrate of potash, the first form being a rhomboid of nearly equal dimensions in all, the second form is a right rhombic prism similarly related in dimensions. In arsenious acid and oxide of antimony, the first form is the regular octohedron, the second a right rhombic prism. In each form these substances are isomorphous, or they are *isodimorphous.*

* Though alike in chemical constitution, the two forms of arsenious acid and garnet may be the result of isomerism. In minerals represented by so complicated a formula as garnet and vesuvian, it is impossible to say that the elements are not very differently arranged, that they are not, in fact, different substances.

II.

15. *Of Isodimorphous Groups.*—In my report on the actual state of chemical science, published in 1832, p. 433*, I drew attention to the remarkable fact that two substances known to be dimorphous, the carbonates of lime and lead, crystallized each in two forms, the analogous pairs of which were also isomorphous. To distinguish this new character I suggested the term isodimorphous, and I stated as probable that we should "soon be able to embrace the whole of the isomorphous groups to which calc spar, and arragonite severally belong in one large isodimorphous group." This expectation has already been partly verified†, while other groups have been discovered connecting other systems of crystallization also, and holding out the promise of large accessions to this branch of knowledge as observations become more extended.

16. The following table comprises all the groups of these substances, and all the members belonging to these groups with which we are at present acquainted.

* Report of the British Association, vol. i.

† See especially the interesting paper of G. Rose, (*Pog. An.* xlii. p. 366), whose experiments are still in progress and promise new accessions to this list, as well as to our knowledge of the circumstances under which the several forms are produced.

TABLE II.

Isodimorphous Groups.

Name.	Formula.	First Form.	M on M	Second Form.	Inclination of the lateral Planes.	Authorities.
I. Carbonate of Lime ...	$CaO + CO_2$	Rhomboid	105° 4′ Mit.	Rt. Rh. Pr....	116° 16′ Ku.	
——— Magnesia	$MgO + CO_2$	Do	107 22½ Mit. / 106 15 Moh.	Do ...	?	G. Rose.
——— Lead	$PbO + CO_2$	Do	104 53½ ?	Do ...	117 14 Ku.	Johnston.
——— Iron	$FeO + CO_2$	Do	107 0	Do ...	118 0 / 108 26 ?*	Dufrenoy.
Nitrate of Potash......	$KO + NO_5$	Do	106 36 Fm.	Do ...	118 52 Lv.	Frankenheim.
II. Arsenious Acid	$As_2 O_3$	Reg. Octohed...	....	Do ...	....	Wöhler.
Oxide of Antimony......	$Sb_2 O_3$	Do ...	....	Do ...	136 58	Do.
III. Sulphuret of Silver...	$Ag S$	Do ...	....	Rhomboid ...	....	H. & G. Rose, Sander.
(Di ?) ——— of Copper	$Cu S$ or $Cu_2 S$?	Do ...	....	Do ...	71 30	Mitscherlich.
IV. Sulphate of Nickel ...	$NiO + SO_3 + 7HO$	Square prism ...	....	Rt. Rh. Pr....	91 10 Bk.	Do.
Seleniate of Zinc......	$ZnO + SeO_3 + 7HO$	Do	....	Do ...	....	Do.

* Dufrenoy leaves it doubtful (*An. de Chim. et de Phys.* p. 204.) which of these values is the correct one. On this point, one of great interest, Poggendorf made some remarks in the xxxivth. vol. of his Annals, p. 666, to which, so far as I am aware, Dufrenoy has published no reply.

Relation among systems of crystallization.

17. *Remarks on the Table of Isodimorphous Groups.*—One of the most striking facts exhibited by this table is the existence of an intimate relation between certain forms not mutually derivable;—between the several systems of crystallization. That these systems are *natural* is proved both by geometrical considerations, and by the fact that the same substance crystallized in forms belonging to different systems possesses different physical properties (13), yet the isodimorphous groups show that there is a relation, not accidental but constant between crystals of a given dimension in one system and crystals of a given dimension in another system. Thus in the first group the

Rhomboid of 105° to 107°	is related to the	Rt. Rh. Prism of 116° to 118°	
Regular Octohedron	———	Rt. Rh. Prism of 139°	in the second.
Do.	———	Rhomboid of 71·30	in the third.
Square Prism	———	Rt. Rh. Prism of 91·10	in the fourth.

18. The form of the crystal is dependent on the form and arrangement of the crystalline molecules; instead however of necessarily agreeing in form with either of those observed in the crystal, the phænomena of dimorphism show that they probably differ from both, and by their union in the direction of one or other of two axes of attraction of nearly equal force build up one or other of the observed crystalline forms. If the connection between the system of crystallization indicated by the table be really of this kind; if forms constantly related in dimension, but belonging to different systems, may be formed by the collocation of molecules of one constant form, it is not impossible that this relation may hereafter be expressed analytically; that more general formulæ may be obtained involving the properties of two or more systems, and by means of which the form and dimensions of the molecules may be deduced from those of the dimorphous crystals which are made up of them, and which we can measure.

Relation between form and density, &c.

19. While tracing the connection of the forms of dimorphous bodies we are naturally led to inquire if any relation be observable between the form assumed and the physical properties which accompany it. Our data are still too few and imperfect to enable us to give any satisfactory answer to this inquiry.

In regard to density, the observations recorded in Table I. would indicate that the same substance—

Sulphur	in the form of a Rh. Octohed.	is more dense than	in that of an Ob. Rh. Prism.
Carbon	———	Reg. Octohed.	———	Rhomboid.
Bisulphuret of Iron and Arsenious Acid		Reg. Octohed.	———	Rt. Rh. Prism.
Carbonate of Lime and Baryto Calcite		Rt. Rh. Pr.	———	Rhomboid.

or that in these forms the molecules are *nearest* to each other in the following order:—

Reg. Octohedron and Cube.
Rhombic Octohedron ?.
Rt. Rhombic Prism.
Oblique Rhombic Prism ?.
Rhomboid.

The hardness of the several forms seems to follow a similar order, the denser of two forms being also the harder. This is certainly the case with the diamond and the arragonitic forms of carbonate of lime and baryto calcite, but the observations we possess on this point are still too few in number, and made, in general, with too little attention to minute accuracy*, to justify us in founding any general conclusion upon them.

20. It will be observed that the several members of each group in the above table are represented by analogous formulæ with a substitution in each of one element only,—a metal. The first group, with one exception, is represented by the general formula $\dot{R}\ddot{C}$ or $RO+CO_2$, and the fourth group by $\dot{R}\dddot{S}+7\dot{H}$ or $RO+RO_3+7HO$ in which not only the entire sum of the negative and positive equivalents is equal, but the sum of those in each member of the formulæ is also equal. Thus in the first of these formulæ $RO+CO_2$ the negative are to the positive equivalents as 3 : 2, and in the two parts RO and CO_2 they are as 1 : 1 and 2 : 1. This is the case with all the neutral carbonates of Protoxides, whether isomorphous or not. In the second for- Isomorphous groups, probably dimorphous.

* M. Frankenheim has observed in regard to the hardness of crystallized bodies, native and artificial, that three orders of differences are to be observed:
1° On the same line in opposite directions.
2° On the same face in different lines.
3° On different faces of the same crystal.
He finds that two directions or faces of the same crystallographic value have always the same hardness, and that isomorphous bodies very different in *absolute* have similar *relative* hardnesses. This is the case, for example, in regard to nitrate of soda and calc spar, the absolute hardnesses of which are so unlike.
These orders of differences he found to be intimately connected with the natural joints of the crystals, so that the hardness is least.
1° In relation to different faces; on the faces of the joints themselves.
2° On each face in the line perpendicular to the intersection which the principal joint would give of that face.
3° On the same perpendicular, in a direction from the obtuse to the acute dihedral angle of the intersection.—Frankenheim *Traité sur la cohesion des corps. Extract Biblioth. Univ.*, June 1836.
By considerations drawn from the relations of the polar forces, supposed to reside in the crystallographic axes of crystallized bodies, M. Voltz has endeavoured to show that the hardness must vary on different faces and in different directions, and according to certain laws (*l'Institut.*, 9th August, 1834).

mula $RO+RO_3+7HO$ the same ratio prevails among the several members in both the substances as yet known to belong to the isodimorphous group it represents.

Now as we know that there are several carbonates isomorphous with the first form of the first group in our table, and several with the second, all of which are represented by the same formulæ, there is reason to believe that they also are dimorphous, and that our knowledge of them *might* be represented as follows:

	Rhomboid.	Rt. Rh. Prism.
Carbonate of Manganese ...	Found native....	Not known.
——— Zinc............	Do. ...	Do.
——— Baryta.........	Not known......	Found native.
——— Strontia	Do. ...	Do.

and so with the rest of the isomorphous carbonates.

In like manner we are justified in looking forward to the enlargement of the fourth group by the addition of the other isomorphous neutral sulphates and seleniates of protoxides with seven atoms of water. It was supposed that the sulphates of zinc and magnesia had been met with in two forms, but later observations of Mitscherlich have shown that the second form contains only six atoms of water.

Like forms generally follow like formulæ.

21. It is *generally* true, so far as observations have gone, that isomorphous substances are analogous in constitution; the ratio of the positive and negative equivalents in the whole formulæ, and in their several members, being the same. The converse of this, however probable it may be, is by no means so generally established. A knowledge of the principle of dimorphism however, and especially of that of isodimorphism, enables us to understand how bodies may be isomorphous and yet not present themselves to us in ordinary circumstances under the same forms. Thus the chromate and molybdate of lead are represented by formulæ, which are analogous in every respect, and contain the common base oxide of lead, and yet they occur in nature in different forms. If we suppose them to be dimorphous, then the ordinary form of each may be considered as representing the second or rarer form of the other, and including tungstate of lead, which is isomorphous, with the molybdate, we have the following isodimorphous groups :—

	Formulæ.	Square Prism.	Oblique Rh. Prism.
Tungstate of Lead...	$\dot{Pb}\,\dddot{Cr}$	Common form ...	Not known.
Molybdate	$\dot{Pb}\,\dddot{Mo}$	Do. ...	Do.
Chromate	$\dot{Pb}\,\dddot{Cr}$	Not known	Common form.

As an illustration of this point we might have taken the sulphate and chromate of lead, of which not only are the formulæ every way analogous, but in which both the acid and the base are known to be isomorphous and capable of replacing each other, or we might have made one group of the sulphate, chromate, and molybdate, which all present themselves in different forms. I have however taken the case of the chromate and molybdate, because I think the probability of the two forms of these compounds being a real isodimorphism is very much strengthened by a specimen in the possession of my friend Mr. Brooke, of London, which he showed me as a molybdate of lead (a square prism the form of the molybdate) having the colour of the chromate. I am not without hopes of obtaining a fragment for the purpose of determining if it does not really contain chromic acid*. The case of substances represented by the general formulæ presenting themselves in more than two incompatible forms will be considered in a subsequent section of this report†.

Like forms with unlike formulæ.

22. But all the members of isodimorphous groups, much less of groups simply isomorphous, are not necessarily represented by formulæ every way analogous. Of this the fourth member of the first group in our table, the nitrate of potash, presents a striking example. In the formula for this salt ($KO+NO_5$) neither the ratio between the positive and negative elements in the entire compounds, nor in the acid it contains is the same with that which exists in the carbonates ($RO+CO_2$) which form the other members of the group.

Among isomorphous bodies, known to assume only one form (monomorphous), it was early observed by Mitscherlich‡ that potash (KO) might be replaced both in neutral and acid salts by ammonia with an atom of water (H_3N+HO), without change of form, though neither the number of equivalents nor

* Since this report went to press I have examined a fragment of this specimen, and found it to be chromate, which has enabled me to insert this compound in Table I. among the other known cases of dimorphism. See Lond. and Edin. Phil. Mag. for May 1838.

† See p. 197.

‡ *Berz. Årsberättelse*, 1833, p. 136.

the number of elements, nor the ratio between the positive and negative constituents was alike in the mutually replacing compounds. As, however, ammonia with an atom of water may be represented by (H_4N+O) the oxide of ammonium; this case was fairly considered as by no means decisive that isomorphous bodies are not necessarily analogous in constitution and represented by analogous formulæ. It may be, as many chemists have thought probable from other grounds, that potassium is itself a compound metal, and that potash, were its true constitution understood, may be analogous with ammonia.

Other compounds, however, were discovered, agreeing in form, yet represented by formulæ not reconcilable according to received views. Of these the earliest known were, that nitrate of soda and nitrate of potash, not then observed to be dimorphous, were severally isomorphous with calc spar and arragonite, and other examples have since been added chiefly by the researches of Mitscherlich. All the known groups of this kind are represented in the following Table. I call them monomorphous, to indicate that as groups with unlike formulæ they are not *all* known to assume more than one form.

TABLE III.

Monomorphous Groups.—The members of which are represented by unlike formulæ.

Groups.	Formulæ.	Common Forms.	Authorities.
1° Ammonia with an atom of water...............	$H_3N + HO$	Replacing each other in many Salts	Mitscherlich.
Potash, Soda ?	KO NaO		
2° Nitrate of Potash	$Ko + NO_5$	Rhomb. of 106° 36′ Fr.............	Frankenheim.
Nitrate of Soda............	$NaO + NO_5$	—— of 106° 30′ Br..........	Mitscherlich.
Calc. Spar..................	$CaO + CO_2$	—— of 105° 5′..............	
Bitter Spar	$MgO + CO_2$	—— of 106° 15′	
3° Nitrate of Potash	$Ko + NO_5$	Rt. Rh. Pr.	Do.
Arragonite	$CaO + CO_2$		
Bitter Spar	$MgO + CO_2$	Do.	G. Rose.
4° Native Sulphur	S	Rhomb. Octohed.	Mitscherlich.
Bisulp. and Biselen. of Potash (from solution)	$\dot{K}\dddot{R} + \dot{H}\dddot{R}$	Do.	
5° Felspar.....................	$\dot{K}\dddot{Si} + \ddot{Al}\dddot{Si}^3$	Ob. Rh. Pr........................	Do.
Fused Bisulph. of Potash	$\dot{K}\dddot{S} + \dot{H}\dddot{S}$?	Do.	
6° Anhydrous Sulphate of Soda (Thenardite) ...	$NaO + SO_3$	Rt. Rh. Pr........................	Do.
Permanganate of Baryta	$BaO + Mn_2O_7$	Do.	

TABLE III. continued.

roups.	Formulæ.	Common Forms.	Authorities.
7° Baryta Harmotome	$2\left.\begin{matrix}\dot{Ba}^3\\ \dot{Ca}^3\end{matrix}\right\}\dddot{Si}^4 + 7\underline{\dddot{Al}}\dddot{Si}^2 + 36H$	Rt. Rh. Pr. of 92° 41′ Köhler .. ——— 110° 0′ Levy	
Lime Harmotome.........	$\left.\begin{matrix}\dot{Ca}^3\\ \dot{K}^3\end{matrix}\right\}\dddot{Si}^2 + 4\underline{\dddot{Al}}\dddot{Si}^3 + 18\dot{H}$		Köhler Pog. Annal. xxxvii. p. 572.
Stilbite (Desmin).........	$\left.\begin{matrix}\dot{Ba}^3 ?\\ \dot{Ca}^3\end{matrix}\right\}\dddot{Si} + \underline{\dddot{Al}}\,\dddot{Si}^3 + 6\dot{H}$	Rt. Rh. Pr. of {91° 16′ Köhler / 94° 11′ Levy	
8° Silica	SiO_3 ?	Rhomboid of {94° 15′ P.......... / 75° 55′ Ku.	The first of these dimensions is given by Phillips and Brooke. The German crystallographers generally adopt the measurement of Kupfer.
Chabasie*...................	$\left.\begin{matrix}\dot{Na}^3\\ \dot{K}^3\\ \dot{Ca}^3\end{matrix}\right\}\dddot{Si}^2 + 3\dddot{Al}\dddot{Si}^2 + 18\dot{H}$	Do. 94° 46′......	Lond. and Edin. Phil. Mag. ix. p. 166.
9° Eudyalite....................	$NaCl + (\dot{Na}^3\dddot{Si}^2 + \dot{Ca}^3\dddot{Si}^2 + \ddot{Zr}\dddot{Si} + \dddot{Fe}\dddot{Si})$	Do. of 73° 46′............	Stromeyer.
Mohsite	FeO. TiO_2. Fe_2O_3 ?	Do. of 73° 43′............	Not yet analyzed.
10° Euclase......................	$\underline{\dddot{Be}}\,\dddot{Si}^2 + 2\dddot{Al}\dddot{Si}$	Ob. Rh. Pr.........................	Brooke, Lond. and Edin. Phil. Mag. x. p. 266.
Zoisite	$\dot{Ca}^3\,\dddot{Si} + 2\underline{\dddot{Al}}\,\dddot{Si}$	Do.	

* Though I have grouped these two substances together, I ought to mention that the crystals of Chabasie are hemihedral, which those of Quartz are not; a distinction which some German mineralogists do not acknowledge among strictly isomorphous bodies.

The seventh group has been inserted on the authority of Köhler, whose paper may be consulted with advantage, and some doubt may be supposed still to hang over the isomorphism of silica and chabasie, though on this similarity of form I have elsewhere* founded an explanation of certain optical phenomena observed by sir David Brewster in some varieties of chabasie, as well as of certain differences in chemical constitution, which specimens from different localities have been found to present.

23. Attempts have not been wanting to reconcile some of the discordant formulæ exhibited by the above isomorphous groups, but hitherto without much success. Thus Dr. Clarke has endeavoured† to reconcile the formulæ for anhydrous sulphate of soda ($NaO + SO_3$) and permanganate of baryta ($BaO + Mn_2O_7$), forming the sixth group in the above table by supposing — *Are these formulæ reconcileable.*

1° That the equivalent of sodium is double of that generally received or $\underline{Na}$, soda being $\underline{\ddot{Na}}$, and an equivalent of the anhydrous sulphate of soda $Na_2O_2 + S_2O_6$.

2° That the acids combine directly with the metals and not with their oxides, and consequently that the rational formulæ for the two salts in question are respectively (representing Na_2 by Na') $Na' + S_2O_8$ and $Ba + Mn_2O_8$ or $Na + \underline{\overset{\cdots\cdots}{S}}$ and $Ba + \underline{\overset{\cdots\cdots}{Mn}}$ in which state the formulæ correspond, and the isomorphism of the two salts becomes intelligible.

The first of these hypotheses must be rejected, I believe for reasons which will find their natural place in a succeeding paragraph (26), the second is so completely opposed to all experimental evidence that chemists could hardly be expected to regard it with a favourable eye even though the first hypothesis to which it serves as a sequel were not deemed inadmissible. Great violence to received opinions must not be offered for the explanation of a *single* apparent anomaly. Each group in the table would probably require one or more *specific* hypotheses to reconcile the formulæ of the several substances which compose it, and these hypotheses, as appears in the following section, might often be conflicting, showing that we are still far from a glimpse of the truth.

Why should it be thought necessary to reconcile the formulæ of isomorphous bodies, except that, carried away by the beauty of the doctrine of Mitscherlich, we have generalized too hastily? If the same substance may crystallize in two or more different

* Lond. and Edinb. Phil. Mag., vol. ix. p. 166.

† Records of Science.

forms, why may not the converse hold? why may not different substances crystallize in one and the same form? We must allow instances to accumulate before we make any *serious* attempts at explanation.

24. It may be proper here to notice a paper by Persoz, in the *Annales de Chimie et de Physique*, No. lx. p. 145, in which, to reconcile the discordant formulæ of certain substances he supposes to be isomorphous, he advances the hypothesis that bodies unite by equivalent volumes, and not by equivalent atoms; and that compounds may be isomorphous which contain equal volumes, either simple or compound. Thus, though the received formulæ for the sulphates and carbonates $\dot{R}\dddot{S}$ & $\dot{R}\ddot{C}$ be different, they may be considered alike if we suppose the acids to be composed respectively of 2 vols. sulphurous acid + 1 vol. oxygen, and 2 vols. carbonic oxide + 1 vol. oxygen, and the neutral sulphates and carbonates may be isomorphous. So also may the nitrates and hyponitrites ($\dot{R}\overset{\cdot\cdot\cdot\cdot\cdot}{N}$ & $\dot{R}\dddot{N}$) be isomorphous since the acids are composed of,

The nitric . . . of 4 vols. nitrous acid + 1 vol. oxygen
hyponitric of 4 vols. nitric oxide + 1 vol. oxygen.

This hypothesis exhibits an unfortunate waste of ingenuity, since it has been proposed to explain two supposed cases of isomorphism, which have in reality no existence. On the authority of Kobell, verified by Voltz, he states that the forms of sulphate of barytes ($BaO + SO_3$) and arragonite ($CaO + CO_2$) are identical*, though the inclination of the lateral faces of the Rt Rh Prism in the former is 101° 42′, in the latter, 116° 10′. They are, indeed, what Kobell calls homoiomorphous†; but so are numerous other substances, the formulæ of which it would be idle to attempt to reconcile. Because also the nitrate of lead (an octohedron) crystallizes without change of form in a solution of hyponitrate ($PbO + N_2O_3$), he concludes that these two salts are isomorphous; and to explain this imaginary identity of form between a sulphate and a carbonate, a nitrate and a hyponitrate, the hypothesis above stated is had recourse to. In the same way he states, that it is impossible to mistake the analogy of form between common Borax ($\dot{Na}\underline{\overset{\cdot\cdot\cdot\cdot\cdot\cdot}{B}} + 10\dot{H}$)

* *An. de Chim. et de Phys.*, LX. p. 119.

† See Schweigger's *Jahrbuch*, vol. iv. p. 410, also Reports of the British Association, vol. i. p. 429.

and common soda $(\dot{\mathrm{Na}}\ddot{\mathrm{C}}+10\dot{\mathrm{H}})$*, and the octohedral forms of the same salts with five atoms of water. Had he been aware of any of the real cases of monomorphous groups having discordant formulæ inserted in the list above given, or had he referred to *them* only, his reasoning, however hypothetical, would not have been so undeserving of a place in the excellent and elaborate memoir of which it forms a part.

Equivalent of Silver.

25. The chemical constitution of the two metallic sulphurets which compose the third of our *isodimorphous* groups, suggests considerations nearly related to those which have just been detailed. If they are really unlike in constitution, and are represented severally by RS and R_2S, then they ought to be included in our list of bodies which are like in form but unlike in formula. It is proper to state, therefore, why they are represented as isodimorphous.

In a former report† I have illustrated the application which has been made of the doctrine of isomorphism in determining which of several possible multiples of a given number should be considered as representing the true equivalent of substances in regard to which we have at present no other means of arriving at a satisfactory conclusion. That alumina, peroxide of iron, and oxide of chromium crystallize in the same form, and are capable of replacing each other, as in the alums, is considered satisfactory evidence that their elementary constitution is analogous—that the ratio of the oxygen to the metal is the same in all, and that the general formula R_2O_3 represents the composition of each. The whole doctrine of replacement, so beautifully applied to the elucidation of mineral compounds, depends on the same principle. *No substances have ever yet been observed to replace each other in atomic proportions, and without change of form, which are not also represented by the same general formulæ.* The nearest approach to an exception yet known is the fact established by Mosander, that peroxide of iron in the titanic irons may replace titaniate of the protoxide of iron (Fe_2O_3 may replace $FeO+TiO_2$); but the exception is only in appearance, for Fe_2O_3 may be represented by $FeO+FeO_2$, in which case the formulæ are still analogous. Ammonia with an atom of water and potash are the only substances in our list of monomorphous substances with unlike formulæ which have been observed to replace each other, and we have already stated

* The form of borax is an obliq. Rh. Pr. PM 101° 30′ MM 86° 40′ } Brooke.
That of common soda ditto PM 108° 45′ MM 76° 12′ }

† Report of the British Association, vol. i. p. 422.

the theoretical considerations by which the force of this objection is for the present, at least, suspended.

If, then, replacement in atomic proportions without change of form imply an absolute analogy of constitution, the sulphurets of copper and silver possess this analogy. In grey copper (fahlerz), represented by the general formula, $\dot{R}^4\overset{\prime\prime\prime}{\underline{R}} + 2\dot{\underline{Cu}}^4\overset{\prime\prime\prime}{\underline{R}}$, the $\dot{\underline{Cu}}$ in the second member of the formula is often replaced by $\dot{Ag}$ (in the silver fahlerz) without change of form. If we suppose $\dot{Ag}$ and $\dot{\underline{Cu}}$ to be capable of replacing each other, all the varieties of the grey copper may be represented by the same formula $\dot{R}^4\overset{\prime\prime\prime}{\underline{R}} + \dot{R}'^4\underline{R}$. But if they replace each other, the forms of these sulphurets as they occur in nature uncombined should be identical. This has not hitherto been observed to be the case. The sulphuret of silver ($\dot{Ag}$) is an octohedron, that of copper ($\dot{\underline{Cu}}$) is a rhomboid. By fusion, however, that of copper is obtained in octohedrons, while that of silver is rhomboidal in the double sulphuret ($\dot{Ag} + \dot{\underline{Cu}}$) from Rudelstadt*. There is every reason, therefore, for believing that these two compounds can replace each other, and that they are not only isomorphous†, but that they form an isodimorphous group, as represented in the table.

It appears, then, in the present state of our knowledge, to follow that the two sulphurets in question are analogous in constitution, and must both be represented by the same formula, $\dot{R}$ or $\dot{\underline{R}}$. It is an interesting coincidence with this result, that the atomic weight of silver deduced by Dulong and Petit from their researches into the specific heats of the metals, is only one half of that which is generally received. From this agreement, and because it involves fewer changes, it is probable that the compounds in question are both *di*sulphurets and represented by the formula $\dot{\underline{R}}$.

* Rose, Pog. *An.* xxviii. p. 427. Sander, *ib.* xl. p. 313.

† If isomorphous, the formula for *Polybasite* $\dot{\underline{Cu}}^9\left\{\begin{array}{l}\overset{\prime\prime\prime}{\underline{Sb}}\\ \overset{\prime\prime\prime}{\underline{As}}\end{array}\right. + 4\dot{Ag}^9\left\{\begin{array}{l}\overset{\prime\prime\prime}{\underline{Sb}}\\ \overset{\prime\prime\prime}{\underline{As}}\end{array}\right.$ might be expressed by $\dot{\underline{R}}^9\overset{\prime\prime\prime}{R}$. For the analysis of Polybasite, formerly confounded with brittle sulphuret of silver (sprödglaserz), see Pog. *An.* xxviii. p. 156.

26. But this conclusion involves several important modifications in the received views regarding the atomic weights of other substances, elementary and compound.

Equivalent of Sodium, &c.

It was observed by Mitscherlich that the sulphate of silver ($\dot{Ag}\dddot{S}$) and anhydrous sulphate of soda ($\dot{Na}\dddot{S}$) agree in form, from which it is inferred that oxide of silver and soda are isomorphous. But if so, they are analogous in constitution; and if the equivalent of silver be halved, that of sodium must be halved also, their formulæ being respectively Ag_2O and Na_2O. Since, also, potash is isomorphous with soda, and may replace it, as in the alums, the rhomboidal nitrates, &c., this oxide also must be expressed by K_2O. And, on the other hand, gold being isomorphous with silver, the oxide of gold will be Au_2O_3, which agrees also with the results of Dulong and Petit, and with the electronegative properties sometimes exhibited by this compound.

It is unnecessary in this place to dwell on these changes. They are *indicated* by the isodimorphism of the sulphurets of copper and silver inserted in the table, but they have not yet been incorporated with *received* knowledge by any of the leading chemists of Europe. The establishment of a very few facts more will render any further hesitation unnecessary*.

Analogy between the formulæ for the Carbonates and Nitrates.

27. The halving of the atom of potash supplies us with a mode of establishing an analogy between the formulæ for the earthy carbonates and that of the nitrate of potash. If potash be K_2O and nitric acid, as it is represented by foreign chemists, N_2O_5, then nitre is $K_2O + N_2O_5$ or $\underline{\dot{R}}'\underline{\overset{\cdot\cdot\cdot\cdot\cdot}{R}}$, or, putting together the positive elements R_4O_6, or $2R_2O_3$. In the carbonates $\dot{R}\ddot{R}$ we have also by putting together the positive elements R_2O_3, or the formula for the nitrate of potash is analogous with that for the carbonates as a whole, though the expressions for neither of the immediate constituents of the two classes of compounds have any analogy.

How far it may hereafter prove true that compounds, as such, may be isomorphous and analogous in constitution, while their several components disagree both in form and in constitution, is at present almost wholly conjectural. I have advanced this mode of establishing an analogy between the nitrates and carbonates, partly with the view of drawing attention to the possible recognition of such a principle as our knowledge advances, and partly of illustrating what I have already stated (22) as to the special hypothesis necessary in almost every case

* See London and Edin. Phil. Mag., April 1838.

for reconciling the formulæ of substances such as those inserted in Table III. That an extension of the general conditions necessary to isomorphism must by-and-by take place, the number of bodies we are already able to insert in this table is sufficient proof*.

Plesiomorphous differences.

28. It would be improper to dismiss the consideration of the tables of dimorphous and isodimorphous groups without adverting to the differences in the angular dimensions of the several substances comprised by these groups. It is true generally of isomorphous bodies, that the angular dimensions of their crystalline forms do not exactly correspond, but only approach to each other often very closely, as in the chromate and sulphate of potash†, but sometimes differing nearly two degrees, as in some of the earthy carbonates. These differences have been much dwelt upon, especially by English crystallographers, to some of whom they have appeared sufficiently great and constant to warrant the rejection of the term *iso* and the substitution of *plesio* morphism in its stead‡. The fact of bodies replacing each other is inconsistent with a mere approach in their forms, while the circumstance that no *constant* difference has been observed among the forms of the several members of the same isomorphous group with different acids or bases, shows, I think, satisfactorily, that these differences do not necessarily imply unlike forms in the crystalline molecules. If the silicates or sulphates of two oxides be almost identical in form, while their carbonates differ by more than a whole degree, the difference between the forms of the oxides not being constant in the analogous classes of compounds, *may* at least have their origin in a cause extrinsic to the forms of the substances altogether.

Cause of.

29. It is well known that Mitscherlich attributed these differences to some peculiarity in the chemical affinities, specific to each substance or to the several substances entering into a compound. On this very probable opinion it is unnecessary to dwell. He has lately, however, thrown out a suggestion in regard to the nature of this specific modification of the affinities, or rather how it operates, an examination of which will be neither uninteresting nor out of place§.

Supposing the molecules of bodies—their mutually replacing equivalents—to be equal in size, and to be placed at like distances, the densities of these bodies should be as the weights of their equivalents. That the densities are not so related in na-

* See London and Edin. Phil. Mag., May 1838.

† Brooke, Annals of Philosophy, August, 1823, and January, 1824.

‡ See Report on Chemistry, Reports of British Association, vol. i. p. 428.

§ Poggendorf's *Annalen*, vol. xli. p. 216.

ture will appear on comparing those of almost any pair or group of isomorphous bodies. The molecules, therefore, of the analogous compounds, even of bodies which may replace each other, are often separated by unlike spaces.

Now in two isomorphous substances exhibiting this difference, the increased distance of the molecules in the less dense may either be equal in every direction, in which case, though the densities are not related as the equivalents, the crystalline form and dimensions of each would remain alike, or the increase of distance may be different in the direction of the several axes of the crystal, in which case the angular dimensions of the two substances in a state of crystallization would more or less vary.

Heat is known to expand regularly crystallized bodies unequally in different directions, enlarging the acute angles and imparting a tendency towards the cube or other forms belonging to the regular system. The suggestion of Mitscherlich is, that *chemical affinity acts in the same way as heat*, drawing in or binding together the molecules more closely in one direction than another, so that if, at the temperature at which two isomorphous compounds crystallize, the affinity between the elements in the one be only a small degree greater than in the other, a difference more or less great must result between the dimensions in the so-called plesiomorphous bodies, that is, the crystals must be plesiomorphous only. And this suggestion is the more probable inasmuch as it accounts for the fact that the plesiomorphous differences do not prevail equally among all the analogous compounds of the same acids or bases; the difference between the affinities of two bases, A and B, for an acid C, being probably unlike, not only in amount, but in sign*, to their difference for a second or third acid D or E.

The close relation which exists between chemical affinity and heat would predispose us to receive with favour the hypothesis in question; but we can so far test it by observation, since it implies that in any isomorphous group those substances whose crystalline dimensions most closely approximate should have their densities also most nearly in the ratio of their atomic weights; and conversely, those which have the acute angles of their crystals the greatest, should also have their densities furthest below what this ratio would indicate.

* In the difference (of the affinities?) of baryta and strontia for the sulphuric and carbonic acids, we have this disagreement both in quantity and in sign.
In the Rt. Rh. Prisms of these substances we have the obtuse angle in

Sulphate of baryta	$= 101°{\cdot}42'$	Carbonate of baryta	$= 118°{\cdot}30'$
——— strontia	$= 104°{\cdot}00'$	——— strontia	$= 117°{\cdot}32'$.

30. In throwing out the suggestion Mitscherlich compares only the carbonates of lime and magnesia. I shall take a greater number of these carbonates in order to test it more closely*.

	Equivalent.	Observed specific grav.	Calculated specific grav.	Diff.	Angle of the rhomboid.	Diff.
Calc spar	632·456	2·721	......	......	105°4′ Mit.	° ′ ......
Carb. of Magnesia...	534·790	2·884	2·30	0·584	106·15 Mohs.	1·11
——— Iron.........	715·65	3·829	3·097	0·75	107·0	1·56
——— Zinc.........	779·663 }	3·379	3·354	0·025	106·30 Phil. 107·40 Woll.	1·26 2·36
——— Manganese	722·337	3·592	3·107	0·485	106·51 Mohs.	1·47

A general agreement with the hypothesis is observable in these substances. The densities are all greater than they should be, compared with that of calc spar, and the acute angles of their crystals less, but no ratio is observable between the differences of density and of angle indicated by the 5th and 7th columns. The observed densities are those given by Mohs, as taken from crystallized specimens, but there is no evidence that the specimens measured were in any case those of which the density was also taken, so that in the absence of more correct data our test cannot be rigidly applied. Different crystals of the same substance have not only different densities but also different angular dimensions. Breithaupt states that the crystals of hornblende vary as much sometimes as 5°, those of pyroxene as 2°, and no doubt the density would vary in proportion. The same observer found the density of a calc spar of 105°·8′ to be 2·741, and of another (tautokline) of 106°·10′ to be 2·968†, both of which cases are accordant with the notion that even in the same substance plesiomorphous differences may arise from condensation or expansion *analogous* to that produced by a diminution or increase of temperature. All these examples show that our determinations of the angles and densities of crystallized bodies must be ranked among *uncertain* knowledge till accurate observations of both are made from one and the same specimen. Such results would enable us to try, it might be

* Taking that of calc spar, in which the acute angle is greatest, as a standard, the specific gravities of the other substances are compared with it and calculated from it.

$$\frac{\text{Sp. grav. of calc spar}}{\text{At. wt. of calc spar}} \times \text{at. wt. of A} = \text{sp. grav. of A.}$$

† Karsten found in two specimens of pure calc spar that the one with the less angle had a density of 2·6978, that with the greater of 2·7064.

would compel us to reject, the suggestion we are now considering.

31. Before quitting this part of my subject I cannot refrain from laying before the reader a tabular comparison of the physical and chemical properties of some of the metallic oxides represented by the general formula R_2O_3, though none of them is yet known to be dimorphous, as they present a beautiful example of the analogies which exist among isomorphous bodies, and as their densities exhibit a relation to their plesiomorphous differences entirely the converse of that which Mitscherlich supposes to exist among the earthy carbonates.

	Equivalent.	Angle of the Rhomboid.	Hardness.	Lustre.	Colour of Crystal.	Sp. gr. calculated from Corundum.	Sp. gr. calculated from Ox. of chrom.
Corundum $\overset{\cdots}{Al}$	321·167	86° 6′ Mohs.	9	Vitreous	Blue, yel., red	....	3·33
Peroxide of Iron ...	489·213	85·58 Mohs. 86·10 Phil.	5·5 to 6·5	Metallic	Steel grey	5·9	4·88
Oxide of Chromium	501·319	85·55 Rose	9	Do.	Black	6·09	

The same difficulty presents itself here as in the former example from the uncertainty of the determinations, but in these substances it is clear either that heat does not expand them so as to make them approach the cube, or that the difference of the chemical affinities considered as the cause of plesiomorphism does not act in the same way as heat does. Peroxide of iron and oxide of chromium are much less dense than they ought to be, compared with corundum, and yet the acute angle of their rhombs is less; or, comparing the first two substances in the table with oxide of chromium their specific gravity is greater than calculation gives it, while their acute angles are less. Can it be that heat in expanding these *acute* rhomboids makes them *diverge* from, while *obtuse* rhomboids it brings *nearer* to, the cubical form?

III.

32. *Of Analogous Chemical Groups, the members of which taken singly are Monomorphous, but which as Groups are Dimorphous.*—In the remarks already made on the table of isodimorphous groups (21) I have adverted to the observation that like crystalline forms *generally* follow like chemical formulæ, and I have illustrated by one example in what way this observation leads us to infer and to look for dimorphism in substances not hitherto observed in more than one form. Almost

every group of isomorphous bodies presents us with additional illustrations. Not only may we expect that entire groups shall prove to be dimorphous, of which we as yet *know* only one or two really to be so, as the carbonates of which those of lime and lead, and the sulphates of which that of nickel is the type; but groups also not even recognised as yet to be isomorphous, though their chemical formulæ are analogous. Thus the tungstate of lime and that of lead occur in square prisms, that of iron and manganese (wolfram) in oblique rhombic prisms, but since all these compounds are represented by the same formula $\dot{R}\dddot{T}u$, the form which one assumes should not be impossible to the other. We know that lime and protoxide of lead are dimorphous in their carbonates; we may expect them to be so also in their tungstates, and since lime and the first oxides of iron and manganese are capable of mutually replacing each other, wolfram may be looked for in square prisms. It has indeed been frequently observed by mineralogists of this form. At Huel Maudlin, in Cornwall, at Schönfeld, and elsewhere in Saxony* it has occurred in square prisms, but these are universally stated to be pseudomorphous, to be casts of previous crystals of tungstate of lime. I have never had an opportunity of examining any of these crystals, but as bearing on the very interesting question how far second forms at least may be inferred from chemical formulæ, the supposed pseudomorphism of the square prisms of wolfram is deserving of a close examination.†

But if dimorphous substances may be so numerous, why are they not so in ordinary circumstances, or why have they not been more frequently observed? Ten years more can scarcely pass without adding greatly to the number of known cases of dimorphism, and suggesting some probable reply to this and other similar questions. If the chemical affinities which two bodies are capable of displaying towards each other may lie dormant, even when the bodies are in juxta-position, till the proper hygrometric or thermometric conditions be attained, so may it be with the molecular attractions by which particles are

* Allan's Manual of Mineralogy, p. 219.

† Since the above was written I have seen Cornish specimens of this mineral in the collection of Mr. Brooke. They are in octohedrons, some of them beautifully perfect; the greater part of them, however, more or less hollow, and certainly presenting the *appearance* of after crystals. Still we are not to despair of finding crystals of wolfram belonging to the pyramidal system, and our search may perhaps be stimulated by the character of its twin crystals, which seem to indicate that though this mineral presents itself in the form of oblique prisms, it may in reality have rectangular axes.—See *Krystallographie* von Gustav Rose, p. 119, and Whewell's Report on Mineralogy, p. 332.

drawn together and built up into regular forms. And as elementary or compound bodies belonging to the same natural family, though possessing in common many properties, the same in kind, yet have them in different degrees, and exhibit them under different circumstances, so may we expect crystallizable substances, analogous in chemical constitution, and possessing like physical properties, to exhibit those properties, in degrees and under circumstances specific to each. Under the same circumstances there may be slight differences between the crystalline dimensions as there are between the chemical affinities of two bodies; they may both be dimorphous, but under circumstances so widely different as hitherto to have escaped our observation, just as certain oxides of chlorine, iodine, and fluorine, which we believe to be possible, have hitherto baffled the attempts of the most refined manipulation.

IV.

33. *Of bodies assuming two or more series of unlike physical properties, but of which the crystalline form belonging to each series has not yet been determined.*—In addition to those substances, the dimorphism of which is established by direct measurement, there is a considerable number, the dimorphism of which is rendered exceedingly probable by the fact of their occurring, in two or more states, physically different. If dimorphism imply a difference in physical properties, as well as in form, we may at least be prepared to look for a difference of form when marked physical differences present themselves*.

The following table contains all the substances generally known to exhibit such physical differences.

* Dumas proposes to include all in one group under the name *Polymorphous.* "Mais pour embrasser tous les phénomènes du même genre il faut dire Polymorphisme sans restreindre à deux le nombre de modifications qu'un corps peut présenter, et comprendre dans la même catégorie toutes les sortes de changemens qui peuvent affecter les propriétés physiques." Leçons sur la Philosophie Chimique, p. 303. I think it better, however, to distinguish between what we know and what we only suspect; to call those substances in which two crystalline forms have been observed *certainly* dimorphous, those in which they have not been observed as *probably* so. The term polymorphous will become necessary as soon as it is *established* that the same substance does crystallize in three or more incompatible forms.

TABLE

Exhibiting the characters of those substances which are known
stalline forms in both states

	Formula.	How obtained.	Density.	Hardness.	Fracture.
1°. Sulphur A & B	S	A by subliming, B by fusing Sulphur	1·99 to 2·05	1·5 to 2·5 ...	Conchoidal or granular
——— C	....	By pouring Sulphur at 200C. into Cold Water	?	Soft and tenacious	....
2°. Phosphorus A	P	Distilling Acid Phosphate of Lime with Charcoal	1·77	Sectile	....
——— B	....	Fusing A at { 66°C. 150F. } and suddenly cooling	?	....	....
3°. Sulphuret of Antimony A	$Sb_2\ S_3$	Found native, also by heating B	4·5 to 4·7	....	....
Do. (Kermes) B......	....	By suddenly cooling A when fused, or by precipit. from Antimonial Solutions	4·15	Harder than A	Conchoidal...
4°. Bisulphuret of Mercury (Cinnabar) A	HgS_2	By subliming B......	8·098	2· to 2·5	Do. ....
Do. (Ethiops Mineral) B	....	Throwing down Hg from its solutions by HS, or cooling A suddenly	....	?	Granular......
5°. Bichromate of Potash A	$KO+2CrO_3$	By fusing Chrome Iron with Nitre ...	2·6027 ? Kr.	....	....
——— B	Do.	Fusing A and allowing it to cool	?	?	....
6°. Sulphate of Potash and Copper A	$\dot{K}\dddot{S}+\dot{Cu}\dddot{S}$	Fusing the two Salts together	....	?	?
——— B	Do.	Formed when the fused mass cools to about 60°F., 15·5C.	....	?	?

IV.

to exist in two states physically different, but of which the cry-
have not been determined.

Colour in mass.	Colour in powder.	Transparency.	Characteristic or Remarks.	Authorities.
Yellow	Yellow	Transparent	See Table I.	
Brown	....	Opaque	After about 24 hours the sulphur generally becomes hard and brittle	
Pale Yellow...	Yellow	Transparent	It is only when very pure, and repeatedly distilled, that it becomes black by sudden cooling. On refusion it becomes yellow	Thenard *An. de Chimie*, lxxi. p. 109.
Black	?	Opaque	....	Dumas *Traité* i. p. 247.
Lead grey ...	Greyish black	Opaque	The second state B. Fuchs has distinguished by the term *Amorphous*, a term, as it appears to me, by no means applicable	Fuchs *Annal. de Pharmac.*, xi. p. 282.
Do. ...	Reddish brown	Thin laminæ transpar.; deep hyacinth red		
Cochineal red	Scarlet red; Carmine when heated	Semitransparent	....	Fuchs, Ibid.
Black	Black	Opaque ?......	Gmelin attributes the black colour to the presence of sulphur	Gmelin's *Handbuch*, i. p. 1290.
Red	Yellow	Transparent	The fused Bichromate on cooling shoots out into crystals, which again fall to pieces after the temperature has sunk to 60° F.	Liebig and Poggendorff, *Wörterbuch*, i. p. 151.
Yellow while hot	Do.	Do.		
Dark green...	Green	Do.	On cooling, the fused mass crystallizes, contracts, and finally expands, swells up, and falls to powder	
Pale green ...	Do.	Do.	....	Herschel, *Berz. Årsberättelse*, 1832, p. 142.

To this list glass has some claim to be added. Its physical properties when annealed, and when suddenly cooled, are known to be very different, and in the second of these states it is said by Guérard* to be possessed of double refraction. As it is doubtful, however, how far any specimens of glass used in the arts may be considered as definite chemical compounds, we cannot as yet draw any certain conclusions from their properties in different circumstances. Common charcoal and graphite are also supposed by some chemists to be modifications of carbon sufficiently distinct to awaken the suspicion that this substance may assume even a third crystalline form.

34. The appearances presented by the bichromate of potash when cooling from fusion, and by the double sulphate of potash and copper, are very interesting. In both cases the change commences, as in the yellow crystals of biniodide of mercury, at one edge of the mass, and gradually spreads over the whole. As in the biniodide, the *changed* is in all probability a *hetoromorphous* state, and the same will, I think, prove true of all the substances contained in the present table. They are necessarily placed apart in the present state of our knowledge till their forms in the changed condition shall have been determined.

The chance, so to speak, of their proving dimorphous is much strengthened by the analogy in constitution between the bisulphate of potash, which is known to assume two unlike forms, and the double sulphate in the table. The formula of the one $\dot{K}\dddot{S}+\dot{H}\dddot{S}$ is the exact counterpart of that of the other $\dot{K}\dddot{S}+\dot{Cu}\dddot{S}$, the copper in the latter replacing the hydrogen in the former. Led by this analogy, I have sought for the same phænomena in other compounds of the same class. Sulphate of potash fuses readily at a bright red heat with the anhydrous sulphates of zinc and of nickel, but on cooling the same change does not present itself, at least under the same circumstances. Under conditions slightly varied we may expect all the compounds represented by the general formula $\dot{R}\dddot{R}+\dot{R}'\dddot{R}$ to occur in two states physically different.†

* Pog. *Annal.*, xxxviii. p. 233.

† The probability of the change in question being connected with dimorphism is strengthened by a recent observation of Mr. Talbot, (Lond. and Edin. Phil. Mag., Feb. 1838, p. 149) that a thin film of nitre, on solidifying from fusion, undergoes, when the temperature falls to a certain point, a change quite analogous to that exhibited by the bichromate and double sulphate in the table, and, as in those substances, diffusing itself from a point over the whole mass. In nitre the appearance is no doubt connected with the two forms it is known to assume.

35. Differences of a less permanent and definite kind are exhibited by various substances, as by some of the metallic oxides at different temperatures, which obscurely point to a second state analogous to that we are now considering as belonging to them also. Thus the protoxide of lead PbO when cold is of a pale yellow, when hot of a bright red; the scales of litharge often retain this hue at common temperatures.

It would be premature at once to explain this and similar appearances by a supposed dimorphism; they are deserving however of a close attention, and though obscure at present, the study of them may lead us to new results.

36. Many compound, especially saline, substances, when exposed to the air or slightly heated, undergo a change analogous to that we are now considering, due, however, not to a mere change in the arrangement of the molecules, but to an alteration also in the chemical constitution. When a crystal of sulphate of zinc with seven atoms of water is heated under alcohol it assumes a new form, but it loses at the same time an atom of water; the same is said also to be the case with sulphate of magnesia. The blue acetate of copper with six atoms of water if heated to 90° or 100° F. changes without *apparent* change of form into the green acetate with one atom of water. On examination, however, the apparently unchanged crystal is found to consist of a congeries of minute crystal of an entirely different form*. The mellate of ammonia, according to Wöhler, undergoes an equally striking change by simple exposure to the air. One of the most curious facts of this description is that observed by Herman in regard to the chloride of lithium. When this salt is allowed to deliquesce in the open air large four-sided prisms are formed. If one of these prisms be taken up in the fingers, and then laid on blotting paper, it becomes opaque at the point of contact, and the opacity gradually spreads over the whole crystal. If now moved it falls into a powder, which again deliquesces in the air and crystallizes†. Changes of this kind connected with loss of water are no doubt very numerous.

37. An appearance observed by Biot, in reference to grape-sugar, appears worthy of a place in the present section. He states‡, that the juice of the grape, before it has been crystallized, causes the plane of polarization of a polarized ray passed through it to deviate towards the left, while after crystallization its solution causes the same ray to deviate towards the right. By crystallization the chemical constitution is unaltered (?),

* Wöhler, Poggendorff, *Annal.*, xxxvii. p. 166.

† Pog. *Annal.*, xv. p. 480. ‡ Taylor's Scientific Memoirs, i. p. 596.

and yet if the optical property is to be depended upon, the arrangement of the molecules in the natural juice must have differed very materially from their arrangement in the artificial solution. Unfortunately we cannot depend on the purity of the natural juice, and therefore it would be premature to draw from this phænomenon any of those curious consequences in regard to the value of optical characters and the possibility of the dimorphous molecular arrangement of a solid body following it into its state of solution—which the absolute chemical purity of the sugar in the natural and artificial liquids would render justifiable.

V.

38. *Of crystallized bodies not known to assume more than one form, which yet exhibit unlike physical properties in different portions of their mass.*—There are certain mineral substances, the crystalline form and chemical constitution of which are known and constant, which nevertheless in their action on light exhibit phænomena apparently inconsistent with the idea that the several parts have the form and composition of the whole. As these phænomena are closely related to those of dimorphism, and may possibly be identical with them, I shall here introduce a notice of the more remarkable cases in which they occur. The greater number of these observations have been made and published by Sir David Brewster.

Apophyllite.—In a paper published in the Edinburgh Phil. Trans., vol. ix. p. 317, Sir David has shown that the crystals of certain varieties of apophyllite consist of different portions acting differently on light: "An individual crystal, with one axis, being symmetrically united with several individual crystals with two axes, so as to constitute a regular crystal." In a single fragment of a crystal of this substance Sir John Herschel also found three portions, each possessing distinct and peculiar properties.—Whewell's Report on Mineralogy, p. 353. In the amethyst he has described an analogous structure.

Analcime.—This mineral occurs usually in icositetrahedrons, made up of twenty-four individual pentahedrons. These pentahedrons exhibit "a species of double refraction, previously found in no other mineral." They possess "planes of no double refraction, having a definite and invariable position, and a portion may be extracted from each separate pentahedron which has no axis at all."*

Chabasie.—Some specimens of this well-known mineral, when examined by polarized light, appear to consist of success-

* Edinburgh Philosophical Transactions, 1824.

ive layers deposited around a rhomboidal nucleus, possessed of positive double refraction. This refraction, however, is seen "to diminish in succeeding layers from a positive state till it disappears altogether; beyond this neutral line it becomes negative, and again gradually increases towards the boundaries of the crystal."*

Diamond, topaz.—A similar observation has also been made by Sir David in regard to the diamond, which he found to consist occasionally of a succession of layers possessing different refractive powers and different densities; and in the 2nd vol. of the Cambridge Transactions he has described the Brazilian topaz as consisting of "a central lozenge, surrounded with a border of a different kind, sometimes with additional variations."†

Traces of double refraction have also been observed by the same distinguished philosopher in many substances, the crystals of which, hitherto observed, belong only to the regular system. Among these are potash-alum, rock-salt, fluor-spar, and diamond. In connexion with the doctrine of dimorphism, these observations are all of value, not so much from the positive information they give, as from their showing us what to look for.

39. The conclusion we are at first sight inclined to draw from phænomena such as those above described, is, that such minerals, though to the eye homogeneous, are in reality made up of parts unlike in chemical constitution as they are in optical properties; and to this conclusion Sir David Brewster appears inclined to give his assent. Mr. Whewell, in his report on Mineralogy‡, thus expresses himself: "There would be something utterly perplexing in this complexity in the structure of objects apparently so simple, if we were to conceive such a kind of composition as formed of independent portions adhering together; but we ought probably rather to conceive these relations of parts as the result of a peculiar state of the equilibrium of the elastic æther which exists within the body, and on which its optical properties depend."

This explanation appears to apply very happily to optical differences exhibited by the several parts of a crystal as a whole, which disappear when it is broken into fragments, as is the case in the dodecahedral crystals of the sulphate of potash§;

* London and Edinburgh Phil. Mag., Sept. 1836, p. 166.
† Report of Meeting of the British Association at Liverpool.
‡ Reports of British Association, vol. i. p. 340.
§ Edinburgh Philosophical Journal, vol. i. p. 6.

but it does not seem to account for the fact that portions of the pentahedrons of analcime may be extracted which possess no double refraction, or for the properties of the several parts of the crystals of chabasie and diamond above referred to. The state of the elastic æther in these separate portions must depend on a difference either in the nature or mutual disposition of the ponderable molecules around which it exists; otherwise the optical properties could be of little value as indices either of chemical constitution or of crystalline form. In other words, if the optical properties observed in these minerals reside in the *crystalline* molecules, and not in the mass, the properties of the different parts must depend on a difference either in the chemical properties or in the mechanical arrangement of the *ultimate* molecules of which they are made up.

I think it very likely that in some instances the former cause operates, in other cases, the latter. The introduction of an isomorphous substance of unlike chemical and optical relations may produce such differences as are observed in chabasie*; a different arrangement of the molecules, without change of composition; a dimorphism—in fact—may produce the singular differences of the several portions of analcime. The double refraction observed occasionally in alum and other regular crystals, points, as it appears to me, to an advanced period of our knowledge, when these and many other substances crystallizing similarly will be proved to be dimorphous.

VI.

40. *Of epigene and pseudomorphous crystals.*—In a former section I have adverted to the subject of pseudomorphous crystals, and to the possibility that some of the forms considered to be such may hereafter prove to be cases of dimorphism†. In connexion with the present subject, therefore, as well as in itself not void of interest, I shall here insert a list of the best known and most common cases of epigene, or changed crystals, and pseudomorphous crystals, or casts, which either occur in nature or can be formed artificially.

* This principle I have illustrated in a short paper in the Lond. and Edinb. Phil. Mag. for Sept., 1836.

† This opinion, in so far as regards the last substance (Serpentine) in the above list, has been recently supported by Dr. Tamnau, of Berlin, (*Pog. Ann.*, xlii. p. 462,) who assigns several weighty reasons for considering the supposed false forms of this substance from Snarum, in Norway, to be the true form of the mineral itself.

List of Pseudomorphous Mineral Substances.

Name.	Form.	Replacing.	Localities and Authorities.
Quartz	Cubes and octohedrons	Fluor Spar	Cornwall, Devonshire, Rochette, Erzgebirge.
———	Rhombs. and prisms ...	Calc Spar	Fontainbleau, Haytor.
(Haytorite)............	Ob. ? rh. prism	Sphene, Datholite ?......	Haytor, Devonshire.
———	Cubo octohedrons	Galena	Rochette, (*Dumont*).
———	Rt. rh. prisms	Sulphate of Baryta......	Do. do.
———	Ob. rh. prisms	Gypsum (lenticular) ...	Mont Martre.
Oxide of Tin	prisms	Felspar and Quartz......	Cornwall.
Oxide of Antimony	Rt. rh. prism	Sulphuret (Sb_2 S_3)......	Saxony, (*Kobell*).
Peroxide of Iron (Martite)	Octohedrons	Magnetic Iron ($\dot{Fe}+\dddot{\underline{Fe}}$)	Do. do.
Hydrated do. ($\dddot{Fe}+\dot{H}$)	Cubes and do.	Iron Pyrites (Fe S_2) ...	Do. do.
Do.	Rt. rh. prisms...........	Carbonate	Styria, Carinthia.
Pyrolusite $\ddot{Mn}$	Rt. rh. prism	Manganite ($\dddot{Mn}+\dot{H}$)...	Saxony.
Minium	Do.	Carbonate of Lead......	
Carbonate of Lead...	Do.	Sulphate of Lead	
Galena (Blue Lead)	Hexagonal prism	Chloro Phosphate	Cornwall, Brittany.
Mixture of Carbonate and Phosphate	Reg. octohedrons	Galena	Do.
Copper Pyrites	Prisms	Lenticular Carbonate and Specular Iron	Cornwall.
Malachite, green Carbonate ($\dot{Cu}^2\ddot{C}+\dot{H}$)	Ob. rh. prism...........	Blue Carbonate ($2\dot{Cu}\ddot{C}+\dot{H}$)	Chessy.
Malachite	Reg. octohed. and rh. dodecahedrons	Red Oxide of Copper...	Do.
Blue Carbonate	Do.	Do. ...	Do.
Gypsum	....	Anhydrite	Pesey.
Do.	....	Sulphate of Strontia ...	?
Sulphate of Baryta...	Rt. and ob. rh. prisms	Carbonate and Baryto Calcite	Hexham, Alston.
Wolfram...............	Square prisms	Tungstate of Lime......	Cornwall, Saxony.
Prehnite	Icositetrahedrons	Analcime	Dumbarton (*Allan*).
Hornstone	Rhomboids, &c..........	Calc Spar	Schneeberg, Saxony.
Steatite	Do.	Do., Quartz, Pearl Spar	Goepfersgrün Bayreuth.
Serpentine	Rt. rh. pr.	Olivine	Snarum, Norway.

41. Pseudomorphic crystals are generally distinguished from regularly crystallized bodies by the absence of the external smoothness and lustre by which *true* crystals are characterized, by exhibiting no internal structure or cleavage, unless very rarely that of the substance of which they have the external form, and frequently by containing cavities or portions of the mineral they replace. In most of the examples contained in the above list, the parasitic formation of the crystals is easily recognized by one or more of these tests; but there are some which betray no such marks of their origin, but, on the contrary, possess all

the external characters of true crystals. Among the latter may be mentioned the cubes of quartz found at Rochette, in the province of Liege, which are so perfect as to have been mistaken by Haüy for the primary rhomboids*, and which are inferred to be parasitic chiefly from the occurrence in the same locality of hollow prisms, obviously casts of previous crystals of calc spar. Similar observations apply to many of the quartz crystals found at Haytor, while the want of internal structure is the chief reason why the hornstones and steatites of Germany, the cubical chalcedonies of Transylvania, and the rhomboidal from Iceland, are classed among pseudomorphous crystals.

The octohedral peroxide of iron (Martite) is one of those minerals which retains the cleavage as well as the form of the mineral (magnetic iron) from which it is derived. The perfection of these crystals has induced Kobell † to consider them as an example of dimorphism, though, perhaps, rather hastily. It is not unlikely that some of the supposed parasitic may be true crystals; but the possession of a distinct cleavage is not alone sufficient to prove that any given crystals are so. Calc spar, after being calcined and deprived of its carbonic acid, still retains its form and cleavages.

42. We can imitate nature in the production even of apparently perfect changed (epigene) crystals. Native crystals of peroxide of iron, heated in a current of sulphuretted hydrogen, give at 212° F. sesquisulphuret Fe_2S_3, and at a higher temperature. Bisulphuret of iron FeS_2, and the new compounds retain the lustre and cleavage of the original crystals.‡ A similar result, without change of form, is obtained from the carbonate of iron. Crystals of bicyanide of mercury at ordinary temperatures may by the same means be converted into black shining crystals of bisulphuret. By simple exposure of the salt to the air, metallic gold may be obtained in the form of the double chloride of gold and ammonia. Nitrate of silver occasionally undergoes a similar decomposition. Many of the salts of lead, silver, and other metals may likewise, by the agency of sulphuretted hydrogen, be converted into sulphurets without losing their form, and very many of the hydrated salts of the earths and metallic oxides part with their water without suffering disintegration.

Still, in connexion with these numerous changes, natural and artificial, one question suggests itself. Are there any limits to the number of forms which the same substance, a metallic

* *Geologie de Liege. Par Dumont.* P. 147.

† *Neues Jahrbuch der Chim. und Phys.* (1831) vol. ii. p. 195.

‡ Berzelius, *Årsberättelse,* 1826.

sulphuret for example, may be made to assume by bringing more powerful chemical affinities into operation? Bicyanide of mercury is completely decomposed by dry sulphuretted hydrogen; bichloride only on the surface. If the latter be previously moistened, it is entirely decomposed; but during the action of the gas, it gradually falls to powder. The phænomena in the latter case are owing to the existence and previous formation of a compound of the two salts, a sulpho-chloride, and not, necessarily, to any inability of the bisulphuret to assume and retain the form of the bichloride; yet it is not impossible that there may exist some unknown relation between the true form of a body and those false forms which it is capable of assuming and retaining in any degree of perfection.

VII.

43. *Of Trimorphous bodies.*—Though we are as yet unacquainted with any cases in which bodies actually assume more than two incompatible forms, yet, as I have already remarked, there is no reason to consider such an occurrence as at all unlikely. On the contrary, there are strong reasons for believing that future observations will make us acquainted with three or more forms of the same substance, geometrically distinct. The analogous compounds, for example, of isomorphous bodies ought to assume the same form, and yet we are familiar with many groups of such compounds which, though their individual members are not known to assume more than one or two irreconcileable forms, yet, *as groups*, are *tri*, or even *tetraki*morphous. In a former section I have illustrated, by reference to one or two cases, in what way the probable dimorphism of individual compounds may be inferred from that of the chemical group to which they belong; the same mode of deduction renders trimorphism almost equally probable. Thus the sulphate, chromate and molybdate of lead, present us with three forms:

			M.M.	P.M.
Sulphate . . .	$\dot{Pb}\dddot{S}$	a Rt. Rh. Pr.	103° 42′	
Chromate . . .	$\dot{Pb}\dddot{C}$	Ob. Rh. Pr.	93° 30′	99° 10′
Molybdate . .	$\dot{Pb}\dddot{Mo}$	Square prisms		
Tungstate . . .	$\dot{Pb}\dddot{Tu}$	Square prisms		

exhibited by substances represented by the same general formula $\dot{R}\dddot{R}$, and which, for anything we know to the contrary, may all be assumed by each other.

Again, carbonate of lime presents itself in three forms:

1°.	2°.	3°.
Rhomboid in calc spar	Rt. Rh. Prism in arragonite and Rt. Rh. baryto calcite	Ob. Rh. Prism in Obliq. Rh. baryto calcite;

and though the third form in this case may result from the combination of the rhomboid of calc spar with the Rt. Rh. prism of heavy spar, yet it is not impossible that it may arise from a true trimorphism.

44. Even simple substances are not exempt from the suspicion of assuming more than two forms. Thus, in many of its combinations with their metals, sulphur belongs to the regular system to which the metals themselves also belong. It is not easy to see how regular forms should result from the union of a cube with either of the known forms of sulphur; it may be considered probable, therefore, that in certain circumstances sulphur may be isomorphous with the metals which belong to the regular system.

Further, it is not unworthy of notice that, among substances assuming regular forms, iron pyrites (FeS_2) and glance cobalt, $\left.\begin{matrix}Co\\Fe\end{matrix}\right\}S_2+\left.\begin{matrix}Co\\Fe\end{matrix}\right\}As_2$ alone exhibit the so called pyritohedral faces. And though we cannot draw any certain conclusions in relation to our present subject from the phænomena exhibited by bodies belonging to the regular system; yet the circumstance now mentioned seems to indicate a connexion between the two minerals not common even among such regular forms. This connexion is most likely to be such as that which exists among the octohedral minerals $\dot{R}\underline{\dddot{R}}$, of which magnetic iron is the type, and among the garnets, namely, that the analogous members of the formulæ by which their chemical constitution is represented are respectively isomorphous, that is to say, that in the two minerals FeS_2 and $R\left\{\begin{matrix}As_2\\S_2\end{matrix}\right.$ arsenic and sulphur are isomorphous, and may replace each other. In addition, therefore, to the two known forms of sulphur, there are two others in which we may still expect to find it, or sulphur may be *tetrakimorphous*.

Rt. Rh. Prism.	Ob. Rh. Prism.	Rhomboid.	Cube.
Native Sulphur, Isomorph. with Iodine.	After fusion, Isomorph. with Selenium.*	When it replaces Arsenic or Antimony.	When isomorhpous with the other metals.

It is not to be disguised, however, that the reasoning in all these cases is at best only probable. The supposition even,—of a fourth form in the case of sulphur depends on a previous one, that in a regular crystal of cobalt glance, arsenic can exist in the rhomboidal form, the only one in which it has hitherto been observed (by Breithaupt). If arsenic and antimony, like the oxides of the latter and the arsenious acid, be dimorphous, one of their forms belonging to the regular system, then the mutual replacement of these two metals and of sulphur in tessular forms, only strengthens the argument for the third or cubical form of sulphur, which is itself also hypothetical.

Still the facts above detailed, and we are acquainted with very many of an analogous kind, are deserving of much consideration. They open up views of great interest, and seem to indicate the line along which the advance of certain knowledge is destined to proceed. Received with caution and due distrust they will materially aid the observer, by teaching him what to look for and how to find it,—received at once as true they will at best form the foundation of an imperfectly verified system of opinions, and may probably lead to error.

VIII.

45. *Relation of dimorphism and molecular arrangement in general, to temperature, electricity, and mechanical pressure.*—Having in the preceding sections exhibited nearly all the facts connected with dimorphism with which we are at present acquainted, it may be proper before inquiring into the cause of dimorphism to take a short review of the several circumstances by which the assumption of the one or the other form is known to be affected.

Influence of temperature.

Of these circumstances the influence of temperature is the most apparent. The various substances which have come under our consideration as capable of existing in two forms or states, are almost uniformly characterized by a preference to one form or state in ordinary circumstances or at ordinary tempe-

* Sublimed and crystallized from its solution in sulphuric acid (Frankenheim) Pog. *Annalen*, vol. xl. p. 459.

ratures, their second form in many being produced, in some being *stable,* only at higher temperatures. Thus the crystals of sulphur from fusion gradually become opaque, and appear to change internally to minute individuals of the common form. The yellow biniodide of mercury even more rapidly changes into the red. The change of form ? undergone by the bichromate of potash and the double sulphate of potash and copper, and of colour by the protoxide of lead, the oxide of zinc, the binoxide of mercury, titanic acid, and other oxides, generally takes place before they arrive at the ordinary temperature of the atmosphere. Whatever be the way in which heat acts, therefore, it is obviously an important agent in the exhibition of the one or the other form by dimorphous bodies.

By an elevation of the temperature, more or less great, the first form is changed into the second, in sulphur, disulphuret of copper, the biniodide and bichloride of mercury, arsenious acid, oxide of antimony, carbonate of lime, carbonate of magnesia, sulphate of nickel, bisulphate of potash, seleniate of zinc, and probably the garnet. Of these substances, however, the new form assumed is permanent in all, with the exception of sulphur and the biniodide of mercury.

Common charcoal readily assumes the form of graphite at a temperature below that at which cast iron melts; of the temperature at which diamond is formed we as yet know nothing.

46. The phænomena attendant on the production of the several forms renders it extremely probable that they are specific in each substance to specific ranges of temperature,—that the form assumed depends upon whether the substance is allowed to crystallize within the one range or the other,—that at temperatures near the limit of each range a very slight cause will set the particles in motion, for the production of either form as in the biniodide of mercury,—and that at greater distances from this limit, either above or below the temperatures to which it belongs, the form is permanent only because the particles have not the power of moving, being coerced as in suddenly cooled glass (Rupert's drops), and requiring time as in sulphur, or the aid of heat as in arragonite, or in the process of annealing glass and metals, to enable them to overcome the restraint and to assume the other form.

Connected as these phænomena appear to be with certain ranges of temperature, they cannot be ascribed to the agency of heat as a cause, otherwise the presence of this agent in greater or less intensity should produce similar effects on all crystallizable bodies; they must rather be attributed to some peculiarity in the molecular constitution of the substances by which they

are displayed, being merely *developed* under certain thermal conditions.

47. The changes that take place in solid bodies at different temperatures, whether in form or in colour, are in general easily observed. In liquids, on the contrary, changes in the molecular arrangement are not so obvious, though there is little reason to doubt that they frequently take place. Of this fact melted sulphur presents the most striking illustration with which we are acquainted. At 230° F. it is very fluid; at 430° F. viscid and tenacious; and again at 480° F., and upwards, of great fluidity. Changes of a different kind are exhibited by hyponitrous acid (NO_3), which at 60° F. is of a green colour, while at $-$ 4° F. it is wholly colourless*. On the other hand, a solution of iodide of starch, which at 200° F. is colourless, becomes blue as it cools. These differences can only arise from some change in the molecular arrangement induced by, or consequent upon, the change of temperature, precisely as in the case of some of the solid substances above described†. Analogous phænomena have not yet been observed in other fluid bodies, either because the change of position in the molecules takes place at temperatures to which fluids are not often exposed, or because it is not often accompanied by changes in the physical properties, such as can be readily observed:—it may be also because they have not hitherto been looked for. It is not unlikely that liquids, whether permanent or obtained by fusion, would at different temperatures differently affect the course of a prolonged ray if tested by the beautiful method of Biot.

48. Even in gaseous bodies the relative position of the molecules does not appear to be the same at every temperature. The vapour of nitrous acid (NO_4), at the temperature of 100° F., is of a deep red, while at 212° it is black and opaque‡ (Brewster). It may indeed be said that in this case decomposition takes

* Mitscherlich, *Lehrbuch der Chemie*, vol. i. p. 342.

† In the Leçons sur la Philosophie Chimique par M. Dumas, which has come into my hands since the text went to press, is a paragraph (p. 305) almost *verbatim* with the above. He adds, "C'est sans doute aux mêmes influences qu'il faut rapporter la propriété que l'eau possède d'avoir un maximum de densité à 4°C, au lieu de continuer à se contracter à mesure qu'elle se refroidit."—p. 336. He seems to have been unaware of the property observed by Sir D. Brewster in the vapour of nitrous acid, as in resuming the facts he had stated, he says, "Vous voyez qu'on arrive à conclure que dans les gaz l'influence de la forme des molecules parait nulle ou presque nulle; qu'elle semble au contraire très-considérable dans les solides, et qu'elle se fait également sentir dans les liquides."

‡ According to Sir David Brewster, a tube, filled with the red vapour at 100° and sealed, becomes black when heated to 212° F.

place $(2\overset{\cdot\cdot\cdot\cdot}{N} = \overset{\cdot\cdot\cdot\cdot\cdot}{N} + \overset{\cdot\cdot\cdot}{N})$ at the elevated temperature, and that as the whole cools combination again takes place; the opacity being in some way caused by the mixed vapours. But this decomposition is by no means probable, and if it were, the change in colour, &c. is still unintelligible, so that, in the present state of our knowledge, the fact remains as an interesting indication of the probable effect of high temperatures on the internal molecular constitution even of gaseous bodies, an effect of which future observation may be expected to furnish us with other examples.

49. *Of Electricity.*—It is not improbable, that like heat, electricity also, to which it is in so many ways related, may have an influence in modifying the arrangement of the crystalline molecules, so as to cause the development of one or other of the two forms.

Mr. Crosse* states, that by passing a weak current of electricity through solutions of carbonate of lime he obtained rhomboidal crystals of calc spar at the negative electrode, and that on one occasion, along with these, he obtained also very fine prismatic crystals, which he took for arragonite, near to the positive pole. It would be very interesting to find this statement confirmed by other observers.

Influence of pressure.

50. In an early part of this report we have seen reason to conclude that the cause of dimorphism acts in such a way as to alter the density of the substance, or the distance at which its crystalline particles are placed. It is therefore interesting to inquire how far such an alteration, induced by purely mechanical means, as by pressure, would affect the form so as to impart to any given substance the characters of a dimorphous body. In so far as the optical properties are concerned, the experiments of Sir David Brewster, recorded in the Philosophical Transactions for 1830, p. 87, seem to indicate that such characters may be imparted by mechanical agency. He found that a mixture of white wax and rosin, which in mass and in ordinary circumstances exhibits no doubly refracting structure, yet has that structure *developed* in it by simple pressure between two plates of glass. The same philosopher has also observed that in mineral substances the optical phænomena are changed in *intensity* by subjecting them to mechanical pressure, in the same way as they are known to change when exposed to a diminishing temperature.

These facts tend to confirm the opinion above expressed, that heat has *no specific* action in producing physical changes in crystalline and other bodies—that it acts merely as any other

* Reports of the British Association, vol. v., Appendix, p. 47.

mechanical cause, the difference of the effects produced in each case being due to the specific properties of the substance itself.

IX.

51. *Cause of Dimorphism.*—From what has been stated in the previous part of this report in regard to the infancy of our knowledge in this department, it will be evident that we are not yet in a condition to do much more than merely hazard conjectures as to the cause of dimorphism. Our observations, however, are already so multiplied that some of the earliest conjectures may now be safely laid aside. I shall briefly notice the several explanations which have hitherto been given.

52. *Presence of a foreign body.*—When the phænomenon of dimorphism was first recognised in carbonate of lime, it appeared most easy to account for the difference between calc spar and arragonite by supposing that the latter actually contained some other ingredient besides carbonic acid and lime. And though the experiments of Thenard and Biot failed in showing the presence of any other constituents, yet the detection of strontia by Stromeyer seemed to set the matter at rest, and the failure of the French chemists was attributed to their deficiency in analytical skill. Now, however, that we can change arragonite into calc spar, and by a proper regulation of the temperature can cause one and the same portions of several other substances to assume either of two known forms, the influence of foreign bodies in these cases can no longer be admitted. It is possible that the presence of such bodies might produce a change of form, but they cannot be considered necessary to the production of a dimorphism, or to afford any insight into the probable cause of the phænomenon.

53. *Influence of circumstances.*—In the preceding section we have seen that the assumption of one or other form by dimorphous bodies is very much influenced by circumstances. Hence dimorphism has been said to be *due* to the different circumstances under which a substance crystallizes. But this is only to look on the surface of the change, and would imply that you have only to vary the circumstances in order to produce another and another form, and that thus the number of forms in which a substance may exhibit itself is limited only by the number of changes that can be effected in the circumstances. It implies also that similar circumstances, or a similar change of circumstances, should produce a similar effect on all substances; but neither of these things is the case, so far as observation has gone; there must, therefore, be something in the internal structure of the mass, in the form, the mechanical arrangement or

physical relations of its molecules, which incline it to assume one or other of a certain number of forms, and to assume each only under certain fixed conditions. Were these conditions fully understood, some light would be thrown on the internal cause; or were the form and relations of the molecules known, we might be able to specify what crystalline forms they are fitted to build up, and under what conditions. It is stopping short however to attribute the phænomena to the circumstances under which they are displayed; for though we may not be able at present to see far beyond them, yet we should be ready to perceive and to avail ourselves of the first glimpse of light.

54. *Change in the intensity of the axial forces.*—The optical phænomena exhibited by certain crystallized bodies, as the topaz, when raised to a high temperature, and of others when submitted to mechanical pressure, have suggested to Sir D. Brewster the idea that under the new conditions, a change takes place in the relative intensity of the axial forces resident in the molecule, and that of this change the new phænomena are a consequence. And as his beautiful researches have shown that the optical phænomena are almost universally true indices of the crystalline form, he attributes the phænomena of dimorphism to a more or less permanent change in this relative intensity of the forces, caused by the circumstances in which the bodies happen to be placed during crystallization. If the attractive forces in the direction of two axes, A and B, be respectively + and −, and if by an alteration of temperature the intensity of the one be elevated and the other depressed, so that they change signs and become respectively − and +, it is easy to understand how, if at liberty to move, the molecules in which this change takes place should make a partial revolution, and build up a crystalline mass of a new form. But this only removes the difficulty a step further back; it merely explains *how* heat and other circumstances may produce the phænomena, it does not affect to explain *why*. The true question still remains behind, What specific relations, mechanical or physical, exist among the molecules of each substance, that the same circumstances do not affect all alike?

55. *Union of the Molecules in the direction of different axes.*—This difficulty is in some measure got over by the supposition of Voltz*. He supposes the crystalline molecules of all bodies to be possessed of three unequal axes, in which reside polar

* *Transactions of the Nat. Hist. Soc. of Strasburg*, 1833. The only knowledge I have of M. Voltz's views is derived from *L'Institut*, 29th March and 8th Aug., 1834, and from a paper by Mr. Dana, in *Silliman's Journal*, xxx. p. 294; it is not impossible therefore that in endeavouring to give a clear statement of his views I may have unintentionally misrepresented them.

forces, the intensity of which is inversely as the lengths of these axes. Further, that these molecules may unite in the direction either of the like or of any of the unlike axes, and that upon the junction or approximation of the axes in which they reside the opposite polar forces unite and neutralize (?) each other as in a chemical compound.

On these suppositions the influence of circumstances is of a less vital character than on that of Sir D. Brewster. They do not alter the relative intensity of the forces, they only affect the mechanical condition—the relative position it may be—of the molecules, so as to allow them to approach and unite in the direction of one axis rather than another.

If the molecules be united in groups three and three, so that the unlike axes unite

$$\begin{array}{ccccc} a & . & b & . & c \\ c & . & a & . & b \\ b & . & c & . & a \\ \hline a+b+c & . & a+b+c & . & a+b+c \end{array}$$

the resultant axes and the forces resident in them are all equal, or the crystal belongs to the regular system. According to Voltz all regular forms are built up in this way.

Again, let them unite in pairs thus,

$$\begin{array}{ccccc} a & . & b & . & c \\ a & . & c & . & b \\ \hline 2a & . & b+c & . & b+c \end{array}$$

and we have a square octohedron, or some other form belonging to the pyramidal (2 and 1 axial) system.

If they unite in equal numbers in the direction of each axis

$$\begin{array}{ccccc} a & . & b & . & c \\ a & . & b & . & c \\ \hline 2a & . & 2b & . & 2c \end{array}$$

we have a crystal belonging, like the molecules* themselves, to the prismatic (1 and 1 axial) system.

It is easy to see that certain dimensions being given for one of these forms, the dimensions of another may be calculated from them on the above suppositions. M. Voltz has so far verified his principle as to deduce the dimensions of the rhomboid of calc spar from those of the right rhombic prism of arragonite, and the form of rutile from that of anatase.

* It is not necessary that the molecules, to meet the views of M. Voltz, should be considered as regular prismatic forms. An oblate ellipsoid has three unequal axes, which would answer all the conditions.

In regard to the difference of physical properties exhibited by the unlike forms of the same substance, M. Voltz considers that the axes as well as the forces resident in each being independent in magnitude, the physical properties in the direction of the three axes must always differ in a greater or less degree. The density, hardness, refraction, reflection, dilatability by heat and compressibility along the unlike axes being unequal in the molecule, must vary also in the crystalline mass with the way in which the molecules are grouped together to form it, and hence the physical properties of the mass will depend in some measure on the system of crystallization to which its form belongs.

These views of M. Voltz may not be correct, yet they are deserving of much consideration. They may embody only a part of the truth, or they may hereafter prove to be wholly in error; yet they have more the air of a *vera causa* than any of the other hypotheses we have considered, and they may be instrumental in pointing the way to something still more satisfactory.

X.

56. *Extent of Dimorphism.*—Is dimorphism or heteromorphism universal; may all substances assume two or more incompatible forms? To this question we cannot at present give a direct reply; there are considerations, however, partly theoretical and partly drawn from observation, which seem to render it probable, that if not all, at least a very great number of crystallizable substances are heteromorphous.

57. According to any of the suppositions (53, 54, 55) by which dimorphism has been accounted for, as above stated, the power of assuming more than one form ought not to be restricted to any number or to any class of bodies whether simple or compound. If it be caused by change of circumstances, all substances may be placed in new conditions; if to a change in the relative intensity of the axial forces, all ought to be more or less liable to such a change; while the theory of Voltz implies, that all being made up of molecules with three unlike axes, may assume one or other of a much more numerous suite of forms than observation has hitherto given us reason to suspect in any one known substance. Still these explanations are all hypothetical; and though we ought not altogether to lose sight of the conclusion to which they would direct us, we are not justified in allowing such theoretical views to do more than awaken in our minds a suspicion that all substances may ultimately prove to be dimorphous.

58. Again, if we turn to the department of observation, and consider how little the forms of bodies have been studied, how

much less even the relations of these forms to temperature and other circumstances of an unusual character have been attended to, we shall see cause to believe that the number of bodies capable of assuming two or more forms must be vastly greater than we can as yet be aware of.

59. In the great majority of cases we have yet to learn where and how to look for the second forms of bodies. This is strikingly illustrated by the beautiful observation of Frankenheim in regard to the crystallization of nitrate of potash from its solution in water. As the evaporation proceeds crystals of two kinds are distinguished, prisms of the ordinary form and six-sided plates of the second form; but as the prisms are prolonged they come in contact with the plates, give rise to an immediate movement among their particles, and incorporate them with their own mass, so that the ultimate result of the crystallization is an unmixed crop of crystals of the common form.

In most cases of crystallization it is only the final result we can observe or have hitherto regarded—may there not be very many cases in which changes analogous to those observed in nitre may take place, a knowledge of which would enable us greatly to enlarge our list of dimorphous bodies?

60. An analogous observation of Ehrenberg* suggests the same question, and makes an affirmative reply still more probable. In examining the crystallization of common salt under the microscope, he states that the first crystals formed were generally six-sided tables, in the centre of which a cubical point would suddenly appear and gradually increase in size, while the tabular crystal dissolved around it and at length disappeared. The hexagonal crystals had much resemblance to the hydrated tables observed by Mitscherlich at very low temperatures, so that the present does not appear to be a case of dimorphism. Still it points in the same direction as the observation of Frankenheim, tells us to keep an eye on the same class of phænomena, instructs us not to rest satisfied with a knowledge of the *final* form of a crystallized body, but if possible to follow the march of the molecules, to note the successive stages at which they seem to rest for a time, and to mark the transformations they may undergo before they reach that form.

61. The circumstances also, the range of temperature for example, within which a certain form can exist, is sometimes very limited. Thus a solution of carbonate of lime in carbonic acid, if allowed to evaporate and crystallize in the cold gives only calc spar, if evaporated on the sand bath it is almost en-

* *Pog. An.* Z. R. vi., p. 240.

tirely arragonite. Chloride of calcium precipitated by carbonate of ammonia in the cold gives calc spar, if both solutions be boiling the result is arragonite; and yet at a low red heat arragonite is again changed into calc spar. Thus it would appear that the conditions as to temperature in which the molecules may unite to form calc spar are various and recurrent, and that so far as we yet know arragonite *is not formed* at a temperature below perhaps 80° or 100° F., and *cannot exist* above 700° or 800° F. It may be necessary therefore to observe the forms assumed by bodies at many different temperatures, not perhaps very remote from each other, before we shall be able to pronounce as to their ability to assume more than one form.

The application of the microscope to the examination of the phænomena of crystallization promises to add much to our knowledge. In the hands of Ehrenberg, Frankenheim, Gustav Rose, and Talbot it has already given us much interesting information, but a rich harvest awaits the further use of this new instrument on a field hitherto almost untouched by it.

62. But the clearest and most extended inference in regard to the number of individual substances which are likely to prove dimorphous (trimorphous perhaps or polymorphous), is to be drawn from the existence of a dimorphism in certain chemical groups, the individual members of which are only monomorphous, or conversely from the known existence of dimorphous individuals in large strictly chemical and isomorphous groups. In a former section (section iv.) we have discussed the probability of a heteromorphism being observed in all the members of the groups of the first class, and of all the members of those of the second class proving *isodi* or *isotri*morphous, and we have seen strong reason to believe that this expectation will not ultimately be disappointed. How great a number of individuals these observations *when made* will add to the substances in our first table need not be pointed out; it is sufficient that in the circumstance here alluded to we see another reason for believing that in nature the assumption of two or more incompatible forms is very far from being a rare phænomenon.

63. Theory and observation therefore unite in suggesting that dimorphism, instead of being an exception, as it still in some measure appears, to the ordinary laws of crystallization, may prove to be a general, perhaps a universal consequence of those laws. The utility of the present report consists mainly in its bringing together the scattered fragments of our *certain* knowledge—in pointing out the inquiries they indicate, and the conclusions to which they lead, and in its setting up a landmark to which it may be interesting, perhaps curious to refer in a fu-

ture and more advanced state of the science, when observation shall have verified some, perhaps falsified the whole of our most likely predictions.

XI.

64. *Relation of the Crystalline doctrine of Dimorphism to the Chemical doctrine of Isomorphism.*—The differences hitherto observed between the properties of the two forms A and B of any dimorphous body are physical only; if we impart to them unlike chemical relations also, they become *isomeric.*

65. The fact that two or more substances may consist of the same elements united in the same proportion, and have the same atomic weight, and yet possess unlike properties, chemical as well as physical, is at least as new to chemistry as the doctrine of dimorphism is to crystallography. Both classes of phænomena are due to a mechanical change in the relative position, distances, &c. of the particles of bodies;—for what we call chemical differences are only physical differences of a higher order. Those of isomerism, however, are more general, implying or carrying along with them those of dimorphism. Isomeric bodies in their several states not only exhibit different chemical properties, but assume also unlike crystalline forms, though the relations among these forms have not as yet been examined with that care which the subject deserves, and would probably well repay.

66. Without affecting to understand how these two orders of differences are actually produced in nature, we can yet conceive how they *might* be produced under certain given conditions. For let the crystalline particles of which sensible crystals are immediately built up be prismatic—have three unlike axes—then according to the views of Voltz dimorphism may be accounted for. But let these crystalline particles be themselves groups (and we are certain that such a particle of a compound body must contain more than one, some many molecules), the several members of which may be collocated at different distances or in different relative positions, and we have, independent of and beyond the supposed cause of dimorphism, another means of producing changes of a profounder character, which may affect the chemical relations of the crystalline particles while it alters also the relative lengths of their several axes. It is immaterial whether the ultimate molecules have the form of prisms, of oblate ellipsoids, or of spheres; it is necessary only that by their collocation they may produce prismatic crystalline forms, and all the known phænomena can be conceived. According to this view, there is a strong analogy between the two classes of phænomena as regards the mode by which they are produced—the

one change commencing as it were where the other ends, and basing itself upon it.

67. There are other analogies also between these two doctrines. Isomerism like dimorphism is dependent on circumstances, is developed in certain cases by change of temperature. Thus according to Löwig* the racemic (paratartaric) acid is changed into the tartaric by simple fusion. The crystals of anhydrous cyanuric acid ($3Cy+6O+3H$) distilled at a heat below redness into a vessel cooled to the freezing temperature, gives a liquid hydrated cyanic acid $3\,(CyO+HO)$, which on attaining the temperature of the air changes into a colourless solid—the *insoluble* cyanic acid. During these changes there is no escape or loss of any of the elements. The polymeric carbo-hydrogens seem to change into one another, in a certain order, by an elevation of temperature; the sugars, gums, and starches also pass into each other by a slight alteration of circumstances, and future observation will doubtless make us acquainted with the conditions necessary for the production of the several members of the known and of many other as yet unknown isomeric groups.

68. Connected as these two classes of phænomena seem to be in their probable origin, and by the kind of circumstances under which they are developed, they may be expected to throw some light on each other. Thus if substances may appear in more than two or three isomeric states, be *isotri* or *isopoly*meric, why may they not also be *tri* or *poly*morphic? In whatever degree we consider these two classes of appearances to be analogous, in the same degree will be strengthened the probability we have already seen to exist, that the forms which the same body may assume are not limited to two or even three.

Can elementary bodies be isomeric?

69. Again, if simple substances, like sulphur and carbon, may assume two incompatible forms, may they not present themselves in two isomeric states? If they are susceptible of that internal molecular change to which dimorphism is due, why not also of that deeper change, as we suppose it, to which isomerism is owing—by which difference in chemical relations is produced?

An affirmative answer to this question will probably be the next great step in chemical science, advancing the knowledge of our time at least as far as the discovery of the alkaline metals carried forward the chemistry of the time of Davy.

70. Meanwhile the probability of such a discovery does not rest merely on a supposed analogy between the phænomena of

* *Pog. An.*, xlii. p. 588.

dimorphism and isomerism; there exist also other observed analogies which point to that reduction in the number of received elementary substances which must necessarily follow the establishment of the supposition that elementary bodies are susceptible of isomerism.

Thus certain compounds, like cyanogen, known by the name of radicals, exhibit all the chemical relations to the elementary bodies by which simple substances belonging to the same class (chlorine, bromine, &c.) are distinguished; the latter therefore may likewise be compound.

Again, the chemical and physical relations of the several states of isomeric bodies are sometimes (cyanogen and paracyanogen) at least as distinct from each other as those exhibited by the several elementary substances comprised in almost any of the natural groups*. This consideration adds weight to the hypothesis that the latter are not simple.

71. The speculations of chemists in regard to the probable diminution of the number of received elementary bodies have hitherto run only in the channel of decomposition. Nor is this surprising, since up to the present time the greatest accessions to our knowledge have flowed to us through this channel. It has been often supposed that any given elementary substance A, as happened with the alkalies and earths, may prove to be made up of two others known or unknown; and that in any two of them, if the constituents prove the same, they may be united together in different proportions. The idea of a possible *transformation* has hitherto hardly been thought of; and yet the doctrine of isomerism, rich already in its numerous discoveries, has shown that any number of the received elementary bodies *may* be made up of the same elements united in the same proportion. That they are so made up is in no degree the less probable, that under no circumstances have we ever observed any two (as iodine and bromine) to be transformed into each other, since even of the isomeric groups few are yet known, the members of which are mutually convertible by methods as yet understood or at our command.

Regarding the question under this new point of view, it will appear that the study of the several kinds of physical and chemical properties which the same portion of matter may assume, and of the circumstances which influence the development of one or other of these kinds, if it do not ultimately solve, is not unlikely to throw considerable light upon this, the most inter-

* Cyanogen is not more like to paracyanogen than oxygen is to sulphur; less so than chlorine is to iodine. See Transactions of the Royal Society of Edinburgh for 1836, vol. xiv.

esting problem now present to the minds of chemical philosophers.

72. *Are the elementary substances isomeric*? is another form of the question, *Are the received elements really compound*? inasmuch as it indicates a desire to diminish the number of the simple substances; but it is a very different question as regards the way in which the number is supposed to be capable of diminution.

For this diminution by the process of decomposition the hopes of chemists rest almost entirely on the application of galvanism or some similarly powerful agent, directed by the skill of a Davy or a Faraday; it may be however that the patient study and pursuit of the kindred classes of phænomena we have been considering, shall in some brighter moment show that substances considered elementary are yet *mutually convertible* without decomposition; while the question may still remain unsettled, perhaps untouched, whether any of them be compound or not. Are the received elements isomeric? is thus preliminary to the question, Are they compound? and in the case of some of them may receive the earlier answer.

73. It may indeed be that all our *supposed* elementary bodies are in *reality* such, and therefore wholly beyond the resolving energy of electricity or any other agent, and yet the study of their changes and reactions in the laboratory, in conformity perhaps with new views or modes of investigation, may at some future period so enlarge our dominion over the molecules as shall cause them at our bidding to assume this or that arrangement—to appear with the properties of chlorine or iodine—of cobalt or nickel—of rhodium, iridium, or osmium.

Such speculations are not only of high interest—they are of use also in suggesting new investigations—in urging the experimenter to try new methods in the hope of being guided to new results. I have ventured to introduce these speculations at the close of the present report, with the view of showing the connection of isomeric and dimorphous differences with the highest questions and objects of research in the existing state of inorganic chemistry. The path along which they lead us is as yet dark and obscure, but it is certain to guide us to rich and open fields, perhaps to some hill top from which new domains may be descried, and from which the descent is easy to new conquests.

74. In the advance of the sciences of observation it is seldom that the same instrument has been the means of producing two great revolutions in the same department. The balance in the hands of Lavoisier overturned the phlogistic theory; but though

the surest weapon of the modern chemist, it is doubtful if it can ever again produce such an overthrow of received opinions. By its aid Dalton and others established the atomic theory; but this was rather a splendid addition to our knowledge than the refutation of a prevailing creed. By the aid of the galvanic battery Davy effected the brilliant revolution with which his name is associated. The line of Faraday's researches, though directed towards a similar end, and strewed along its whole course with beautiful results, has yet led him to no higher dominion over refractory matter; and though we have much to hope for from the wonderful weapon he has learned to wield so skilfully, we have reason also to fear lest if we trust to this weapon alone we should ultimately be disappointed. With the goniometer Mitscherlich has gained for science those remarkable branches of knowledge, to the actual state of one of which it has been my object to draw the attention of British philosophers in the preceding report; and it is not a little remarkable that the progress of these branches of knowledge seems likely to be arrested by the same question which electricians since the days of Davy have often asked themselves, Are the elementary bodies really simple? Which of these branches of inquiry is destined to solve the difficulty—will the honour be shared by each—or must a third branch arise, bearing a new weapon to carry away the glory from both?

I cannot close this report without noticing more fully than I have yet had an opportunity of doing how very much this department of knowledge has been indebted to Professor Mitscherlich of Berlin. To this distinguished philosopher we owe the first recognition of the principle of dimorphism, as well as the subsequent discovery of many of the most interesting examples of its manifestation with which we are yet acquainted. In reading his various memoirs on this and kindred subjects, it is difficult to determine whether we should admire most the ingenuity and extreme beauty of his researches, the brevity and clearness with which his most important results are announced, the grave and philosophic air which pervades his deductions, or the unity of purpose observable even in the most seemingly insignificant of his published investigations. The order of his memoirs exhibits not only the progress of his own inquiries, but at the same time of the branches of knowledge he has created. In his own walk he has trodden almost alone, and there is perhaps in our time no other example among the sciences of observation of an entire department depending for so many years on the single labours of one individual. It is to be presumed that many

understand the researches of Mitscherlich, that some at least are qualified to go forward in the same path with himself, yet no one has ventured to shoot out into the main current of his inquiries or to dispute with him the honour of leading the advance. It is certain indeed that in *all* the necessary qualifications,—in knowledge of the subject, and in devotion to its advancement, as well as in intellectual gifts and acquirements, no living philosopher could replace the present leader. Could any other be expected to prosecute it so zealously as he whose mind has given it birth?

We may be permitted therefore to wish and hope that the labours of this distinguished observer may be long continued to us, that he may win new laurels to himself and add new domains to the sciences he has already so greatly enriched. If the present report make his discoveries more familiar to the rising philosophers of our own country, or lead into the field of dimorphism one mind yet undecided what path of science to choose, its main objects will not be wholly unattained.

Desiderata.—1. To determine the physical differences which exist between the incompatible crystals of the same dimorphous substance. (See blanks in Tables I. and IV.)

2. Within what limits of temperature is each form stable? within what other (?) limits may each form exist. (61.)?

3. In general we are acquainted only with the final result of crystallization: do bodies not *pass through* (so to speak) one or more forms as they crystallize till they ultimately assume one more stable than the rest? The microscope will aid this inquiry. (60.)

4. In isomorphous groups of which one member is dimorphous, to observe if, under certain circumstances hitherto neglected, the other members may not also be dimorphous. If mineral substances, specimens from different localities should be studied and measured. (20.)

5. In groups represented by like chemical formulæ,—but the several members of which do not all assume the same form (32.),—to determine if the several known forms belonging to the group do not also belong or may not be assumed by each member of the group. (32.)

6. When two series of unlike physical properties (33.) are assumed by the same chemical substance, to observe if each series includes a different crystalline form.

7. In the present state of the doctrine of isomorphism it is of importance to collect and tabulate examples of like form in

substances represented by unlike formulæ. (See Table III.) They seem to point to a modification of received opinions.

8. In cases of reputed pseudomorphism to examine minutely the circumstances under which the changed crystals occur, and the nature of the crystals themselves; some of them may prove to be cases of dimorphism. (40.)

9. To observe by the aid of the microscope or otherwise the change which fusible substances undergo in the different stages of cooling after solidification. Some (5. 6. Table IV.) substances appear in cooling to *pass through*, as it were, intermediate forms which they cannot retain, before they reach that state of crystalline arrangement which is proper to the stationary temperature. If one substance be known to exhibit such transformations, to inquire if all substances represented by the same formulæ may exhibit them.

10. What difference of molecular arrangement, as indicated by the optical properties, exists in the viscid state of melted sulphur compared with the limpid states it assumes at a higher and at a lower temperature (47)? Are analogous phænomena, differences of colour, density, fluidity, &c., observable in other fluids at different temperatures? Can any other gases exhibiting like changes be added to the solitary example of nitrous acid? (48.)

In connexion with this subject every accurate measurement of a crystal, every *nice* determination of the hardness or density of a well crystallized specimen, and above all every careful analysis of specimens *previously measured and weighed* is of great value. For *though* not immediately available in clearing up any obscure or disputed point, they will form a sound basis for future reasonings, will indicate new analogies among crystalline compounds, and will gradually lead us forward to wider generalizations.

Durham, 1838.

Special Report on the Statistics of the Four Collectorates of Dukhun, under the British Government.

[In spelling Oriental words, the *a* is the *a* in *all*, the *u* as in *hut*; the rest have the usual English sound.]

The General Committee of the British Association which met at Cambridge in 1833, did me the honour to pass a resolution that I should prepare for publication my manuscripts respecting the Statistics of Dukhun (Deccan). I have been anxious to respond to so flattering a desire at an earlier period, but having placed my manuscripts in the hands of a distinguished person, as auxiliary to his scientific labours, I have been deterred from reclaiming them until the objects for which they had been placed at his disposal were realised.

In responding at last to the call of the British Association, I feel very considerable embarrassment in adapting my materials to the space which can be afforded to me in its annual volume. The materials, in fact, are very voluminous; and the nature of my subject embracing multitudinous details, figured statements, and lengthened tables, makes it a work of no ordinary difficulty to digest, abridge, and condense them without involving my subject in obscurity, and exposing myself to the imputation of inefficient inquiry from the hiatus which must appear. I beg, therefore, distinctly to state, that the absence of information observable in the following Report, is attributable, not to paucity of matter, but to the want of a sufficient field in which to display it.

Extent and Physical Circumstances.

I propose to give but a meagre sketch of the statistics of Dukhun; a mere enumeration of its population, products, manufactures, revenues, civil divisions, &c., with little more comment than may be necessary to ensure perspicuity.

In the execution of my public duties as Statistical Reporter to the government of Bombay, my researches made me acquainted with the statistics of the four collectorates of Dukhun, denominated the Poona, Ahmednuggur, Candeish or Khandesh, and Dharwar Collectorates; facts were also collected respecting the territories of the Rajah of Sattarah, and some few details came to hand illustrative of the state of the possessions of the southern Mahratta Jagheerdars, which are

under British protection. In adverting to the whole of these territories, although I shall name them separately in describing their extent, physical circumstances, and civil divisions, it will only be to notice where they differ from each other.

The whole of the above territories, containing 3,285,985 inhabitants, spread over 48,987 square miles, and averaging 67 inhabitants to the square mile, lie upon that elevated plateau, which has an abrupt termination on the western side of India, in what are usually denominated the Ghàts, but which plateau gradually declines, occasionally by a succession of low steps, as is seen by the courses of rivers to the Coromandel coast, excepting in Khandesh (Khind meaning a gap or trench, and Desh a country,) where the river Tapty disembogues to the westward, from the peculiar configuration of the narrow valley in which this collectorate lies. Some of the platforms on the summit of the Ghàts have an elevation of 5000 feet above the sea, but the general level of the main plateau of Dukhun is about 2000 feet high near the Ghàts, and scarcely exceeds 1000 feet in the eastern limits of the collectorates. The whole territory is mountainous near to the Ghàts, and has numerous valleys, some of them narrow and tortuous, others broad, open, and flat. At from thirty to fifty miles eastward from the Ghàts, most of the mountain spurs which produce the valleys terminate, and the country becomes open and tolerably level for considerable distances, with an occasional step down to the eastward; the country, in fact, being made up of beds of trap, the beds extending the further to the eastward the lower they are in the series. There is much forest and underwood and jungle along the line of the Ghàts; but to the eastward the country is open, and there is a want of wood; parts of Khandesh and Dharwar are exceptions to this description. The western tracts along the Ghàts are called the Mawuls, in contradistinction to the open country, which is called the Desh or Dès.

It may be as well to state here that all lands in Dukhun are classed within some village boundary or other, and this boundary is maintained with such jealousy and tenacity by the inhabitants, as to lead to frequent feuds and bloodshed on the slightest invasion of village rights. The village constitution and the occupancy of lands will be mentioned under land-tenures.

Rivers.—The rivers of Dukhun, which in the monsoon flow with a magnificent volume of water, in the hot season present a broad gravelly bed, with only a thread-like stream in many of them, but from natural barriers of rock in the bed of the

Beema, Godavery, Kistnah, and other large rivers of Dukhun, extensive sheets of water, called Dho or Dhao, are formed, which abound with fish.

Roads and Bridges.—The roads in Dukhun, with the exception of two great military roads, are untouched by art; and few of the rivers can boast of a bridge.

Geology.

Previously to entering into descriptive details, I will state in a few words, that the whole country comprised within my boundaries is composed of distinctly stratified trap rocks, without the intervention of the rocks of any other formation. Whether at the level of the sea, or at the elevation of 4500 feet, in all and every part beds of basalt and amygdaloid are found alternating, whose superior and inferior planes preserve a striking parallelism to each other, and, as far as the eye can judge, to the horizon. Barometrical measurements and the course of rivers indicate a declination of the country to the east-south-east, and south-east; from the town of Goreh, latitude 19°·03 and longitude 74°·05, on the Goreh river, following a mean course for the river until it falls into the Beema, and subsequently, continuing a mean course for the Beema, until its junction with the Seena river, the distance is about 200 miles, and the declination 671 feet: there may therefore be a trifling dip of the strata; but as a succession of low terraces occur in that distance, the apparent horizontal position of the strata may be unaffected by the above difference of level.

Dr. M'Culloch, describing the overlying or trap rocks, says, "these masses are generally irregular, but sometimes bear indistinct marks of stratification*." As Dr. M'Culloch's language implies the rare occurrence of stratification, instead of its being a distinctive feature, at least, of the Indian branch of the trap family, I deem it necessary to quote the few authors who have written on Indian geology, in confirmation of the fact I have stated †.

* *Classification of Rocks*, p. 466.

† "These mountains (the Vindhya range), like every other in Malwa, appear to be distinctly stratified, consisting of alternate horizontal beds of basalt or trap, and amygdaloid. Fourteen of these beds may, in general, be reckoned, the thinnest at the top, and rapidly increasing in thickness as they lower in position, the basalt stratum at the bottom being about 200 feet thick." Again, at page 327, he says, "In the upper plains of Malwa, every point of view presents the same uniform and distinctly streaked appearance noticed in the Vindhya range."—*Captain Dangerfield, in Geological Notices of Malwa, in Appendix*, No. 2, *to Sir John Malcolm's Central India*, pp. 322, 327.

Ghàts.—The Dukhun rises, by a succession of terraces or steps, very abruptly from the Konkun: its valleys and table-lands have a mean elevation above the sea of about 1800 feet. The Konkun is a long strip of land, from thirty to fifty miles in breadth, lying between the Ghàts and the sea: the mean elevation of this strip is less than 100 feet; but it is bristled with isolated hills or short ranges, some of which attain an elevation equaling that of the Ghàts. Numerous shoulders or salient angles are thrown out from the Ghàts, from the western or Konkun side, and by means of these the ascent to Dukhun is affected; with what difficulty, will be understood when I state that the military road of communication between Bombay and Poona, up the Bore Ghàt, rises nearly 600 feet in a mile. The western portion of my tract along the crest of the Ghàts is exceedingly strong: spurs of different lengths extend from the main range to the eastward and south-east, leaving many narrow tortuous valleys between them, some of which have the character of gigantic cracks or fissures; other valleys, although occurring less frequently, when looked at from the neighbouring ranges appear as flat and smooth as a billiard-table, even to the Ghàts; but when traversed, are found to be cut up by numerous narrow and deep ravines. Stupendous scarps, fearful chasms, numerous waterfalls, dense forests, and perennial verdure, complete the majesty and romantic interest of the vicinity of the Ghàts. As the spurs extend to the east and south-east they diminish in height, until they disappear on approaching the open plains in my eastern limits, between the Beema and Seena rivers. The area of the table-land on their summit often exceeds that of the valley between them; such is the case with the spur bordering the left bank of the Beema river for forty miles from its source, occupying, in fact, the whole country between the sources of the Beema and Goreh rivers.

The spurs are rarely tabular for their whole length, but narrow occasionally into ridges capped with compact basalt, and subsequently expand into extensive table lands. The spur originating in the hill-fort of Hurreechundurghur affords a good example. The fort is about eighteen miles in circumference. On the east, it presents a salient angle to the

Dr. Voysey, in a paper on the Geological and Mineralogical Structure of the vicinity of Nagpoor, says, "From the summit of the hill of Sitabuldee the difference in the outline of the rocks eastward is very perceptible. The flattened summits and long flat outline, with the numerous gaps of the trap hills, are exchanged for the ridgy, peaked, sharp outline of the primary rocks." —*Physical Class of the Asiatic Researches*, p. 127.

neighbouring mountain; absolute contact, however, only commences at about 400 feet from the top of the scarp, leaving a gap and an extremely narrow ridge, over which lies a difficult footpath of communication between the valley of the Malsej Ghàt and that of the Mool river. The spur then widens; some lateral ramifications shoot out, on one of which is situated the fort of Koonjurghur. At the Brahmun Wareh pass it narrows considerably, but not into a ridge; it subsequently expands into the extensive and well-peopled table land of Kanoor and Parneir, twenty-four miles long by twenty broad, having diminished in height by a succession of steps from 3894 feet in Hurreechundurghur, to 2866 at Brahmun Wareh, 2474 at Parneir, and 2133 on the terrace of Ahmednuggur. From Ahmednuggur the spur bends southwards until it is finally lost in the neighbourhood of Sholapoor. It is, in fact, the margin of a great plateau, which has a mean elevation of about 300 feet above the valley of the Godavery river, and over which the rivers Goreh, Beema, Seena, &c. take their course. The basaltic caps of the ridges appear more or less columnar from numerous vertical fissures; the weathering of these exposed rocks produces pillars, spires, towers, houses, and other forms of works of art. Another feature of these spurs is the occasional occurrence on their table lands of small hummocks or conical hills with a truncated apex. Dr. Voysey mentions "groups of flattened summits and isolated conoidal frusta" in the Gawelghur Trap Mountains. One of the longest of the spurs originates in the Ghàts north-west of Sattarah, and runs nearly east-south-east about 100 miles towards Punderpoor.

The spur immediately south of Poona, on the ramifications of which are situated the formidable fortresses of Singhur (4162 feet) and Poorundhur, (at nearly the same elevation) has an extent of ninety-five miles.

Valleys.—Much having been said respecting valleys of excavation, I think it may be acceptable to offer a few observations on the valleys between the spurs. I shall describe only those that present the greatest contrasts to each other.

Valley of the Mota River.—The valley of the Mota river, south of Poona, originating in a mass of hills on the edge of the Ghàts, is so exceedingly narrow that for some miles the bases of the opposite hills frequently touch each other, leaving at intervals little horizontal plots of a pistol-shot in width; these plots occur in terraces, on lower levels, as they extend eastward.

Vale of the Under.—The valley of the Under river, north-

west of Poona, presents a perfect contrast to the last. It is level for twenty miles, running east and west to the very edge of the Ghàts; and a person can stand at the head of the valley, upon the brink of a scarp, rising almost from the Konkun. Here, at the source of the river, it is nearly six miles wide. The river Under runs down the valley 150 feet below the level of the cultivated lands.

If these valleys be valleys of excavation, the present rivers could scarcely produce such, were we to suppose their powers of attrition in operation from the origin of things even to the end of time!

Those of a fissure-like character might have resulted from the upheaving of the beds of trap from below the sea, and the consequent probable fracture of the surface; but the same explanation will not apply to those valleys associated with the preceding, broad, flat, and margined by scarped mountains, which valleys are as wide at their origin at the crest of the Ghàts, and at the sources of the rivers which run through them, as in any part of their length.

Terraces.—As the rise from the Konkun to the Dukhun is by terraces, so the declination of the country eastward from the Ghàts is by terraces; but these occur at much longer intervals, are much lower, particularly in the eastern parts, and escape the eye of the casual observer. In the neighbourhood of Munchur, on the Goreh river, there are five terraces rising above each other from the east to the west, so distinctly marked that the parallelism of their planes to each other and to the horizon gives them the appearance of being artificial. An artificial character also pervades the form of many insulated hills; some of which, viewed laterally, appear to have an extensive table-land on the summit; but seen endways, look like truncated cones. Conoidal frusta, in the Gawelgurh range, have been already noticed. Other insulated hills are triangular in their superficial planes, as the forts of Teekoneh (three-cornered) and Loghur.

Escarpments.—Stupendous escarpments are occasionally met with in the Ghàts. In these instances the numerous strata, instead of being arranged in steps, form a continuous wall. At the Ahopeh pass, at the source of the Goreh river, the wall or scarp is fully 1500 feet high; indeed, on the north-west face of the hill fort of Hurreechundurghur, the escarpment can scarcely be less than double that height. On the other hand, the steps are sometimes effaced, and a hill has a rapid slope. This originates in a succession of beds of the softer amygdaloids, without any basaltic interstratification; their superior

angles disintegrate and a slope results. But most usually three or four beds of amygdaloid are found between two strata of compact basalt; the former disintegrates, leaving a slope, which is not unfrequently covered with forest trees, forming a picturesque belt. The basaltic scarp remains entire, or it may be partially buried by the debris from the amygdaloids above; but its great thickness usually preserves it from obliteration, and it rises from the wood below with majestic effect, its black front being finely contrasted with the rich and lively green of its sylvan associate. It is these strata, arranged in slopes and scarps, repeated three or four times, and so commonly met with in insulated and other mountains in Dukhun, that constitute the amazing strength of the hill forts of the country, leaving a succession of natural walls encircling a mountain. This feature did not escape the observation of Captain Dangerfield in Malwa, who says, "From the great difference in the resistance made to decomposition by these trap and amygdaloid beds, their exposed ends acquire a very distinct degree of inclination and character; the amygdaloid forming a great slope and affording a loose mould covered with vegetation, the trap retaining its original perpendicularity and dark bareness."

In the alternation of the strata there does not appear to be any uniformity; but the general level, thickness, and extent of a stratum are preserved, as in sedimentary rocks, on both sides of a valley; the basalt and hardest amygdaloids being traceable for miles in the parallel spurs or ranges; but the imbedded minerals, and even the texture, vary in very short distances.

Columnar Basalt.—A great geological feature of Dukhun is the occurrence of columnar basalt. The basalts and hardest amygdaloids run so much into each other that the line of separation is not always readily distinguishable, excepting, of course, the lines of horizontal stratification. I observed the prismatic disposition more marked and perfect in the basalt strata than in the amygdaloids, and the more or less perfect development of determinate forms was dependent on the compactness and limited constituents of the rocks. Basalts and amygdaloids, however compact, with many imbedded matters, rarely formed columns. Perfect columns were generally small, of four, five, or six sides; but the prismatic structure sometimes manifested itself in basaltic and amygdaloidal columns many feet in diameter. A bare mention of the places where they occur would testify to their extended localities, but these are too numerous for insertion in this report.

Schistose Structure.—Following the preceding formation, I

may mention, that in some few places a schistose structure was met with, but its extent was limited to a few yards; the lamellæ were vertical, from an inch to three inches in thickness, being perfect tables, with parallel bounding planes. The rock in which this structure occurs is a simple, indurated, gray clay, which flies into fragments under slight blows from the hammer. At Dytneh, near Serroor, some very perfect specimens have led the inhabitants to connect mystic influences with so artificial a development of inorganic matter. The spot is daubed with oil and red lead, and venerated.

Basalt en Boules.—Another characteristic feature, is the general diffusion of those rounded or oval masses of compact basalt, with concentric layers like the coats of an onion, which the French geologists denominate *Basalt en Boules,* and ourselves, nodular basalt*.

Dykes.—I now pass to the basaltic dykes, several of which came under my notice in different parts of the country. They are all vertical, and I did not observe that they occasioned any disturbance or dislocation in the strata of basalt and amygdaloid, through which they passed.

The gentlemen whose geological memoirs I have quoted, rarely advert to the subject of trap dykes, and their notices are very brief. Captain Dangerfield says, "The trap of the southern boundary of Malwa is much intersected by vertical veins of quartz, or narrow seams of a more compact heavy basalt, which appears to radiate from centres." Beyond the continuous trap region of the peninsula, Dr. Voysey notices a basaltic vein in syenite, near the Cavary river at Seringapatam, which must have been propelled upwards, as it broke through an oblique seam of hornblende in the syenite, and carried the pieces up above the level of the hornblende vein. "On the eastern coast," Mr. Calder says, "from Condapilli northward, the granite is often penetrated, and, apparently, heaved up by injected veins or masses of trap and dykes of green stone."

Ferruginous Clay.—The next distinctive feature is the

* Dr. Voysey says, "The nodular wachen or basalt is one of the most common forms of trap in the extensive districts composed of the rocks of the family south of the Nermada (Nerbuddah) river. It occurs perpetually in the extensive and lofty range of mountains (the Gawalghur) situated between the Purna and Tapti rivers, and appears to form their principal mass. It is found equally abundant throughout the whole of Berar, part of the provinces of Hyderabad, Beder, and Sholapoor, and appears to form the basis of the great western range of trap hills which separate the Konkun from the interior of the Dukhun."—*Physical Class, Asiatic Researches,* pp. 126, 189.

occurrence of strata of red ochreous rock; in fact, M'Culloch's ferruginous clay underlying thick strata of basalt or amygdaloid, precisely as is seen to be the case in the Giant's Causeway in Ireland. It passes through every variety of texture, from pulverulent, friable, and indurated, to compact earthy jasper. The stratum is from an inch in thickness to many feet. The rock makes a red streak on paper, with the exception of the very indurated kinds, and does not affect the needle: it is pulverulent near the basaltic columns at Serroor, friable under subcolumnar red amygdaloid, near the source of the Seena river, indurated under basalt at Kothool. Although hard, it is here so cellular as to have the appearance of sponge, and, reduced to powder, looks like brickdust.

Pulverulent Limestone.—Limestone is met with in the Dukhun only in three states—pulverulent, nodular, and crystalline. The first occurs in thin seams on the banks of rivers and water-courses, and at the base of hills in debris: the seams are from an inch to three feet in thickness, covered by a few feet of black earth; sometimes in whiteness it resembles pounded chalk, and is then used by children to smear their writing boards.

Nodular Limestone.—The nodular limestone, which is the well-known kunkur of India, (kunkur being a native word for nodule,) occurs like the preceding, disseminated or diffused in the soil, and also on the surface. I have never seen the nodules of a regular crystalline form; they vary in size from a marble to a twelve-pound shot, and many of them are exceedingly irregular in shape, particularly those dug from the banks of rivers; they are sometimes obscurely lenticular; they are so abundant in certain localities that they appear as if showered upon the earth, and disguise its colour. Dr. Buchanan mentions the same fact in Rajmahl. When upon black soil they are usually minute, and tolerably uniform in size; on other soils their form is variable. In the Ghàts, neither pulverulent nor nodular lime is met with. It is unnecessary to particularize the localities of the nodular kind, as it is of common occurrence eastward, from the hilly tracts of the Ghàts, and is the only source of lime for mortar; a class of persons making a livelihood by collecting the larger nodules. When carefully burnt they make an excellent cement.

Captain Dangerfield describes the occurrence (in Malwa) in some parts, particularly near the bottom of the small hills and banks of the rivulets, of a thin bed of loose marl or coarse earthy limestone. Captain Coulthard says, "In Sagar a white patch of this limestone mouldering by the weather is

the source from whence come the particles of kunkur mixed with the black basaltic earth of the neighbouring valley, in such proportion as to add increased fertility to it; and, if a rivulet meanders through that valley, (and such is generally the fact), patches, made up of aggregated particles of the same, will here and there be found; and this it is which the native families pick out and work into lime." Captain Coulthard refers the origin of the nodules to limestone rock underlying basaltic strata, but I cannot trace them to such a source, not having seen strata of compact limestone, properly so called, in the Dukhun. The only specimen of compact limestone met with by me, was in the bed of the Beema river, near Pundurpoor; it was an insulated, amorphous, gray mass, four or five feet in diameter. I looked upon it as an aggregation of the pulverulent particles of lime disseminated in the neighbouring banks.

Crystalline Limestone.—Lime in a crystalline state occurs only as an imbedded mineral in the amygdaloidal strata in quartz geodes, and in the nucleus, or compact part of masses of mesotype or stilbite. It is rare compared with the preceding varieties.

Loose Stones.—Another feature of Dukhun is the occurrence of immense quantities of loose basalt stones, as if showered upon the land; also masses of rock heaped and piled into mounds, as if by the labour of man. Their partial distribution is not less remarkable than their abundance. For the most part the stones have a disposition to a geometrical form, and it is by no means rare to meet with prisms of three or four sides and cubes almost perfect; stones with one or two perfect planes are very common. Their texture is close-grained, and the colour verging to black.

Rocky Heaps.—The singular heaps of rocks and stones above noticed occur at Kanoor, Patus, Kheir, between Kurjut and Meerujgaon, and at other places in the Mawals, or hilly tracts of the Ghàts. The heaps are from twenty to seventy feet in diameter, and the same in height. When composed of rocky masses, without small stones, blocks of three or four feet in diameter, and with a disposition to determinate forms, are piled upon each other, constituting rude pillars. In certain parts of the country from fifty to sixty of these heaps are seen within the area of a couple of square miles, and it excites surprise that the intermediate ground is destitute of stones.

Sheets of Rock.—Mention must not be omitted of the constant recurrence of sheets of rock of considerable extent at the surface, and totally destitute of soil; this is particularly the case

in the Mawals, or hilly tracts along the Ghàts. They abound with narrow vertical veins of quartz and chalcedony. When of sufficient thickness the vein splits in the centre, parallel to the surface of its walls, the interior being drusy with quartz crystals. The walls consist of layers of chalcedony, cachalong, horn-stone, and semi-opal. These veins supply the majority of the siliceous minerals so abundantly strewed over Dukhun.

Structure and Mineral Composition of the Trap Rocks.—The structure and mineral composition of trap rocks in Dukhun vary exceedingly in short distances, even in the same stratum; nevertheless, the predominant character does not disappear, although the basalt, in a continuous bed, may pass several times from close-grained, compact, and almost black, to grey, amygdaloidal, and externally decomposing. The same observation applies to the amygdaloids. A variety of compact basalt, of an intense green colour, is susceptible of a brilliant polish, and rivals the celebrated Egyptian kind. It is of great weight and remarkable hardness; the natives use it to work into idols for their temples, pedestals to the wooden columns to their mansions, and slabs for inscriptions. The bulls, of the size of life, always placed before the temples of Mahadeo, are cut out of this variety at Raseen, Wurwund and the renowned Boleshwur. Some of the pedestals in the gateway of the Mankéswur palace at Teimboornee, look like mirrors. In the temple of Pooluj, south of Punderpoor, there is a slab six or seven feet long, and two and a half broad, covered with an inscription in the Kanree language; and in Punderpoor the streets are paved apparently with the same basalt. At Jehoor, and near Ahmednuggur, is found a compact kind, like the last, but not so heavy; it has a crystalline character, and sharp fracture, and has angular siliceous pebbles imbedded: an occasional pebble is found loose in its cell. In the Happy Valley, near Ahmednuggur, the basalt is compact and smooth, with reddish flat transparent crystals imbedded. It opposes a feeble resistance to the hammer, and flies into fragments, some of which have right angles. The basalt, even of the true columns, is not of a uniform texture in different localities; at times it is blackish or grey, and very small, granular, or compact; at others, earthy and ferruginous, particularly externally. The base of the amygdaloids is clay, with more or less hornblende disseminated; they embrace the cellular, porphyritic, hard, friable, and decomposing. I endeavoured to class them agreeably to the prevalence of quartz, chalcedony, lime, mesotype, or stilbite, as imbedded minerals, but found the method of very limited

application; sometimes one mineral only is imbedded, occasionally two, and often the whole.

In Hurreechundurghur quartz amygdaloid prevails; at Aklapoor, on the Mool river, it is characterized by mesotype, that mineral being imbedded in large masses, and the radii (six or seven inches) are the longest I have seen; at Nandoor it is porphyritic, with several crystalline specks of lime; near to Ahmednuggur is seen a cellular, indeed spongiform kind, which is hard, and the cells are empty. A small cellular and pisiform variety is found in the wonderful cave temples of Ellora; and some of the sculptured figures appear as if marked by the small-pox. This observation is partially applicable to the Boodh and Hindoo cave temples of Elephanta, Salsette, Karleh, Joonur, the Naneh Ghàt, and the Adjuntah Ghàt, all of which are excavated in basaltic or amygdaloidal strata. The stilbite, or heulandite amygdaloid, is of very common occurrence; but the most prevalent kind is that in which all the minerals noticed above are associated. The stone usually selected for building is of various shades of grey or bluish grey; has hornblende disseminated in very small crystals; works much easier than some of the compacter basalts, but takes a good polish. The entire temples of Korrul and Boleshwur, with their innumerable alto-relievo figures and laboured ornaments, are built of this variety of trap, which is, in fact, a greenstone, although less crystalline than the European rock. There is a variety, selected carelessly, also used in building, which has the structure, and nearly the external characters of the last, but which in weathering exfoliates, and the buildings fall to ruin: such is the case with the great temple in Hurreechundurghur.

I must not omit mention of two remarkable rocks which, as far as my reading extends, have not been noticed by authors on European geology. The first is an amygdaloid, in which compact stilbite is imbedded in a vermicular form; one of its localities is the insulated hill on which stands the temple of Purwattee, in the city of Poona; and it is met with in many other places. Captain Dangerfield* observed the same peculiar stratum near Sagar. He says, "There occurs an amygdaloidal or porphyritic rock, consisting of a compact basis of wackè, in which are imbedded in great abundance small globular or uniform masses, but more usually long, curved, cylindrical, or *vermiform* crystals of zeolite."

The other rock occurs as a thick stratum of amygdaloid,

* Malcolm's *Central India*, p. 328.

at the elevation of 4000 feet, in the hill forts of Hurreechundurghur and Poorundhur, and in the bed of the Goreh River at 1800 feet, near Serroor. The matrix resembles that of the other amygdaloids, but the mineral imbedded is a glossy felspar in tables resembling Cleavelandite, crossing each other at various angles, and so abundant as to occupy a moiety of the mass. I have only remarked it in the above localities, and it does not appear to have come under the notice of the gentlemen I have quoted elsewhere.

Minerals.—Minerals are not uniformly dispersed in Dukhun. In one part quartz predominates, in another chalcedony; and these are more or less associated with jaspars, agates, hornstones, heliotrope, and semi-opal or cachalong. In other places, particular members of the zeolite family prevail, nearly to the exclusion of the siliceous class; and elsewhere there is a diminution of minerals amounting almost to privation. Amethyst quartz is rare in Dukhun; when met with it constitutes the crystal lining the interior of geodes of agate. I have not seen it in veins.

Pseudomorphous quartz is common; the most frequent impression is that of rhomb spar. Lime occurs only in three crystalline forms; rhomb, dog-tooth, and the dodecahedron. The first is found on the surface, and imbedded in masses of quartz and compact mesotype; the two latter forms are associated with ichthyophthalmite in cavities in the amygdaloid strata. That comparatively rare mineral ichthyophthalmite is very common at Poona.

Natural Salts.—Only two kinds of natural salts came under my notice, namely muriate and carbonate of soda; both are not uncommon; the first near to Ahmednuggur, Koond, Mawleh, and other places; the latter at Kalbar Lonee. Saltpetre is artificial in Dukhun.

Ores.—No other ore than that of iron is found in Dukhun. It occurs as a nodular hematite, associated at the source of the Kistna with laterite. This ore produces the celebrated Wootz steel.

Organic Remains.—I did not meet with organic remains of any kind whatever; and Captain Coulthard in Sagar, Major Franklin in Bundelkund, and Captain Dangerfield in Malwa, were equally unsuccessful; and Mr. Calder, in his *General Observations on the Geology of India,* says, "But hitherto the most striking phænomenon in Indian geology is the almost total absence of organic remains in the stratified rocks and in the diluvial soil." Very recently shells are understood to have been

found by Dr. Malcolmson on the edge of the great trap region in the province of Nagpoor. The organic remains from the base of the Himalaya mountains are well known.

Thermal Springs.—I am not aware of thermal springs in the collectorates of Poona, Ahmednuggur, and Dharwar; but in Khandesh, in the pergumahs of Arrawud and Amba, in the Sautpoora mountains, are the hot springs called Soonup Deo and Oonup Deo; the first is so hot that the hand cannot be borne in it, agreeably to the testimony of Colonel Briggs. Hot springs are numerous in the Konkun, bursting through trap; and they are met with in Canara, and in many other parts of India and Ceylon.

Extent of the Trap Region.—The trap has been traced continuously to Neemutch, lat. 24°·27, N. at 1476 feet above the level of the sea, from a fluctuating southern line, which extends down as low as the 15th degree of latitude, but one end of which terminates on the western coast, between the 16th and 17th degrees of latitude; and the eastern end of the line runs up to Nagpoor, at 1000 feet above the sea. The longitudinal extent of the trap, between the above latitudes, would appear to be from the western sea coast (excluding Goojrat) to the 82nd degree of E. longitude; there is thus evidence of a continuous trap formation covering an area of from 200,000 to 250,000 square miles!! However extraordinary this extent may appear, it is an undoubted fact that offsets from this great region extend even to the Ganges! I am not aware of any facts to guide the judgement in the estimation of the age of the trap formation.

Laterite.—Laterite is met with at the source of the Kistna river at 4500 feet above the sea, and its extensive occurrence all round the peninsula of India in the narrow tract of land at the foot of the Western and Eastern Ghàts is well known.

Nodular Limestone.—Kunkur, or nodular limestone, occurs everywhere in Dukhun, indeed all over India.

Granite.—Although granite does not occur in the four collectorates of Dukhun, unless in the extreme southern limits of Dharwar, it is the chief rock eastward of Nagpoor, and it bursts through the surface in so many places in the peninsula of India as to have induced Dr. Voysey to express a belief that the basis of the whole peninsula is granite; an opinion involving the necessary deduction, when the extent of the trap region is also considered, that the whole peninsula of India, and the island of Ceylon, roughly calculated at 700,000 square miles, is of igneous origin.

Sedimentary Rocks.—There are not any sedimentary rocks in Dukhun, nor am I aware of any south of Broach, excepting such as have probably originated in the consolidation of comparatively recent alluvium.

Climate.

A detailed account of the atmospheric tides, and meteorology of Dukhun having been published in the *Philosophical Transactions*, I shall limit myself to a description of such broad features as characterize the climate. The Ghàts and the Desh have distinct features. The tract along the line of the former has a lower mean temperature, much more moisture, greater prevalence of westerly winds, a more limited range of the thermometer; but a greater prevalence of fogs before, during, and after the rains, but not in the winter months; and, finally, is characterized by the absence of hot winds. The Desh, on the contrary, has the air excessively dry in the hot months; a great diurnal and annual range of the thermometer, a comparatively small fall of rain in the monsoon, the frequent occurrence of hot winds, and the rareness of fogs.

Barometer.—The mean monthly pressure of the atmosphere is greatest in the winter months of December and January; it gradually diminishes until July or August, the most damp months, when it is at its minimum; it gradually increases again until the cold months. The greatest diurnal oscillation recorded by me in several years' observations was ·1950, or less than two-tenths of an inch; the smallest oscillation ·0150. The mean rise of the barometer from sunrise to 9—10 A.M. for three years was ·0445, thermometer $+ 7^{\circ}{\cdot}15'$. The mean fall from 9—10 A.M. to 4—5 P.M., for four years, was ·1066, thermometer $+ 5^{\circ}{\cdot}21'$; and the mean rise from 4—5 A.M. to 10—11 P.M., for one year, is ·0884, thermometer $- 7^{\circ}{\cdot}2'$. The maximum range of the barometer at Poona, in the year 1830, at 1823 feet above the sea, was only ·672, or not seven-tenths of an inch. The mean height of the barometer for that year was $27^{\circ}{\cdot}9254$, and the mean height in the monsoon was $27^{\circ}{\cdot}8447$; so that the constant moisture of the monsoon only occasioned a mean diminution of pressure of ·0807, or less than one-tenth of an inch. At Madras, for twenty-one years, the mean height of the barometer was $29^{\circ}{\cdot}958'$ inches; at Calcutta, the means of three years make it 29·764. M. Arago, at Paris, by nine years' observations, reduced to the level of the sea, makes the mean height 29·9546 inches, being almost identical with the mean height at Madras.

Atmospheric tides.—There are four tides of the atmosphere in Dukhun, as indicated by the movement of the barometer; two diurnal, and two nocturnal: the diurnal rising tide is from 4—5 A.M. to 9—10 A.M., and varies from ·0200 inches to ·0500 inches; the falling tide is from 9—10 A.M. to 4—5 P.M, and varies from ·1950 inches to ·0150 inches. The nocturnal rising tide is from 4—5 P.M. to 10—11 P.M., and varies from ·0450 inches to ·1140 inches; the nocturnal falling tide is from 10—11 P.M. to 4—5 A.M., and is about ·0442 inches. This order was never deranged or inverted in one single instance in many thousand observations.

Temperature.—The climate of Dukhun is subject to very considerable variations of temperature; more, however, in the diurnal than in the monthly or annual ranges; indeed, less so in the last particular than in Europe. In 1827, the extreme range of the thermometer at Edmonton was 75° Fahrenheit; at Cheltenham, 64°·6. In St. Petersburgh, the thermometer has been as low as 35°·7′ *below zero*, and as high as 91°·4; the range, therefore, 127°·1. At Berne, the annual range has been more than 75°. In 1826, I observed a range of 53°·4, viz., from 93°·9 on the 12th March, to 40°·50 on the 15th January at sunrise. In 1827, the maximum range observed by me was 48°·8, viz., from 96°·8 on the 28th March, to 48° on the 12th December at sunrise. In 1828, the maximum occurred on the 7th May, being 101°, and the minimum was 56°, the range, therefore, 45°; but, for a very short time, the thermometer rose on the 7th May, between two and three o'clock, to 105°; and this was the more remarkable as I was then encamped on the edge of the Ghàts at the source of the Beema river, at an elevation of 3090 feet above the level of the sea. This instance of unusual height of the thermometer, however, is not confined to Dukhun, for we learn from M. Arago, that it has been higher than 101° Fahrenheit in the shade in Paris.

Monthly means.—The monthly *means* do not differ more than from 13° to 17° from each other. In 1826, the difference between the hottest month (May, 83°·28), and the coldest (January, 65°·90), was only 17°·38. And in 1829, March was the hottest month, and November the coldest, their difference of means being 13°·66.

Diurnal range.—The greatest diurnal range in 1826 was on the 5th March, being 37°·30, from 50°·5 to 87°·8. In 1827, it was 39°·5, on the 12th December, from 49°·5 to 89°. In 1828, it was 34°·8, on the 16th July, from 56° to 90°·8. In 1829, the maximum diurnal range was 37°·5 in December. The minimum diurnal range occurs in the monsoon months of

June, July, August, and September; indeed, occasionally, on some days in those months, the mercury does not move at all.

Mean Temperature.—In 1828, Dr. Walker, at Ahmednuggur, at an elevation of 1900 feet above the sea, made the mean temperature 78°; and though I was living in tents, and moving about the country, I made it only 77°·93. Of course, on higher or lower levels this mean temperature will be diminished or increased. It is necessary, however, to note one remarkable fact, namely, that the mean temperature of places on the table-land of the continent of India is much higher than the calculated mean temperature of the *same* places agreeably to Mayer's formula. The calculated mean temperature of Ahmednuggur is 72°·27, observed 78°; of Poona 72°·78, observed 77°·7; of Mhow, in Malwa, 69°·86, observed 74°: temperature of a spring in the hill fort of Hurreechundurghur 69°·5, calculated temperature 65°·45.

The results of several years' observations indicate that the annual mean temperature of 9°·30 A.M., is nearly identical with the mean temperature deduced from the maxima and the minima.

With respect to the greatest diurnal, and the greatest monthly range of the thermometer, the winter months have a range nearly in a quadruple ratio to the monsoon months. The latter have mostly the temperature very equable, the difference of the monthly means rarely exceeding 3°, and the greatest diurnal range in five years only once amounted to 13°·6. The latter end of March, and April, and May are the hottest periods of the year, from the position of a nearly vertical sun, the intensity of whose influence is but slightly modified by the occasionally cloudy weather: the temperature falls in June, and continues nearly stationary until the end of September: it then rises in October, but falls at the end of the month, until its annual minimum in December or January. It is low the early part of March, but rises *suddenly* after the middle of the month, occasioning a difference of 6° or 8° between the means of February and March, which is more than double that of other consecutive months in the year. The rise in October is also sudden, but does not occasion so great a difference of means as between February and March. It will thus be remarked that the temperature does not follow the sun's declination, owing to the interference of the monsoon.

Moisture.—A remarkable feature in the climate of Dukhun is the small quantity of aqueous vapour generally suspended in the air, compared with the proximate climate of Bombay and

the coast, or even the hilly tracts of the Ghàts. My observations were made with Daniell's hygrometer, and extended over several years. There is a gradual increase of moisture in a cubic foot of air, from the most dry month, February, until June and July. Hence the moisture remains nearly stationary until the beginning of October, when it diminishes somewhat rapidly and regularly until February. The annual mean dewing point is greater at 9½ A.M. than at sunrise or at 4 P.M., but this does not uniformly hold good in each month of the year. In 1826, the highest dewing point was at four o'clock on the 21st October, being 76°, temperature of the air 84°·5, a cubic foot of air holding 9·945 grains of water. The lowest dewing point was on the 4th December, at sunrise, being 44°, temperature of the air 56°, a cubic foot of air containing 3·673 grains of aqueous vapour; but the lowest dewing point did not indicate the driest state of the atmosphere, as a dewing point of 45° in November, with a temperature of 87° at 4 P.M., gave only 3·587 grains.

The most moist month was July; the mean weight of water in a cubic foot of air was 8·775 grains, and the point of saturation was only 4°·85 from the dewing point. The greatest monthly range of the dewing point was, in October, 30°, and the smallest range, 7°, was in July and August. The monthly range was not coincident with the movements of the barometer and thermometer; but there were curious approximations. The extreme dewing points differed 32°. The dewing point has been as high as 76°, temperature of the air 79°, a cubic foot of air containing 10·049 grains of aqueous vapour; but this is a rare occurrence. An instance occurred of the dewing point being obtained at 3° below the point of the congelation of water, the temperature of the air being 62°, and a cubic foot of air holding 2·146 grains of water. There is also an instance of a dewing point, in February, 1828, being 61° below the temperature of the air, viz., from 90° to 29°, but I never afterwards succeeded in determining anything like so great a depression.

In January, 1827, there was a range of the dewing point of 38°, and the extreme range of the year was 47°, viz., from 29°, temperature 62°, in January, to 76°, temperature 79°, in June. In 1829, the mean dewing point for the monsoon was 69°·62, temperature 75°·83; the cubic foot of air containing 8·191 grains of water. In 1830, the observations are only complete for 9–10 A.M.; the mean dewing point was 61°·9, temperature 78°·4, and a cubic foot of air contained 6·351 grains of water; the extreme range of the hygrometer was 47°, the lowest

dewing point 31°, temperature 50°, in December. It might be supposed that the hottest months in the year, March, April, and May, would also be the driest; but such is not the fact. The powerful action of the sun on the ocean, in the middle of March, raises a large quantity of aqueous vapour, which continues to increase in the ratio of the sun's progress north: the westerly winds waft this vapour into Dukhun; much of it is arrested by the Ghàts and hilly tracts eastward of these mountains; accounting for the sensible moistness of the air, the frequent night fogs, and deposition of dew in this line, in the end of March, and in all April and May. The supply of moisture diminishes in proportion to the distance eastward from the sea, to the limits of the Coromandel coast monsoon. We in consequence find the Ghàts, Poona, Ahmednuggur, and the Bala Ghàt, all with very different dewing points in the hot months.

The hygrometric state of the air in Bombay and Dukhun is remarkably contrasted: in fact, there is more aqueous vapour suspended in the air in Bombay in the hot months, than there is at Poona at any time during the monsoon. In April and May, 1826, in Bombay, the monthly mean dewing points were respectively 72°·84 and 75°·59, temperature 83°·48 and 84°·52, a cubic foot of air holding 8·988 grains, and 9·748 grains of water suspended; whilst July, the most rainy month during the monsoon, at Poona, had only a mean of 8·775 grains of water suspended. In 1827, the means of ten days' observations in Bombay, in April, gave 10·243 grains of aqueous vapour in a cubic foot of air; and the greatest mean quantity at Poona was in June, and it amounted only to 8·931 grains. In 1828, in the month of March, the following were the dewing points in consecutive days, travelling from Bombay to Poona; Bombay, 10th March, 4 P.M., 11·205 grains of water in a cubic foot of air; at Poona, at the same hour, on the 14th March, 2·273 grains. At Bombay, on the 10th, at sunrise, and at 9½ A.M., the dewing points were respectively 72° and 71°, temperature 75° and 81°·5, a cubic foot of air containing 8·873 grains at the former hour, and 8·487 grains at the latter hour. The following morning at Kundallah, on the top of the Ghàts, 1744 feet above the sea, at the same hours, the dewing points were 36° and 40°, temperature 72° and 78°, equivalent only to 2·690 grains, and 3·004 grains of water in a cubic foot of air. In the afternoon of the same day, at Karleh, 2015 feet above the sea, seven miles east of Kundallah, a cubic foot of air held 2·954 grains, and on the 12th, at 4 P.M., 2·611 grains of aqueous vapour. On the summit of the hill fort of Loghur,

3381 feet above the sea, and 1366 above Karleh, the dewing point at sunrise on the 13th, was 5° Fahr. below the freezing point, temperature of the air 67°, and a cubic foot of air held only 1·995 grains of water in a state of vapour. These facts fully establish the remarkable discrepancies between the hygrometric state of the air in Bombay and Dukhun, and that too within a difference of a few miles of latitude and longitude. A comparison of the absolute falls of rain in Bombay and in Poona, for the years 1826–7–8, shows an agreement (to a certain extent) in their ratio to the hygrometric state of the air at Poona and Bombay, above noticed. The mean fall of rain at Bombay in those years was 93·62 inches, and at Poona 26·926 inches, or $28\frac{3}{4}$ per cent. only of the fall in Bombay.

Rain.—In Dukhun the rains are light, uncertain, and, in all years, barely sufficient for the wants of the husbandman, and a slight failure occasions much distress. They usually commence at the end of May, with some heavy thunder showers from E. to S.E., the lightning being terrific and frequently fatal, and the wind furious; but they do not set in regularly until the first ten days in June, and continue until the end of September from the W. to the S.W., and break up with thunder-storms from the E. to the S.E. before the middle of October. During the remaining months of the year an accidental shower or two may fall from the Coromandel monsoon; and the further the distance eastward from Poona, the greater the chance of showers in the cold months. The monsoon temperature is equable and agreeable, and the rain occurs almost always in showers, rarely continuing uninterruptedly for a day or more, as is common on the coast and in the Konkun. The greatest quantity of rain falls in the months of June and July. The greatest fall of rain in any one day was 2·58 inches, on the 6th July, 1826; at Bombay, on the 24th June, 1828, there fell 8·67 inches; and at Hurnee, on the 15th June, 1829, there fell 8·133 inches in 24 hours.

The mean annual fall of rain for all England, from many years' observations, appears to be 32·2 inches, but the means of different counties vary from 67 inches in Cumberland to 19 inches in Essex.

The clouds supplying the monsoon rains in Dukhun would appear to have a low elevation, as I have frequently seen through breaks as they were passing swiftly from west to east, a superior stratum, apparently stationary, or moving slowly in a contrary direction, and gilded by the sun's rays.

Winds.—The great features in the observations respecting the winds, are the prevalence of winds from the west and westerly

quarters, east and easterly quarters, and the extreme rareness of winds from the north and south, and the points approximating to them; and these features appear to be constant in successive years. In 5229 observations the wind blew from the west, or points adjoining, 2409 times; and in this number the S.W. (305), and N.W. (122), amount only to 427. From easterly points 949 times, including 246 from the N.E. and S.E., thus leaving 703 from the east. From the north 115 times, and from the south 36 times only. Another feature is the frequent absence of wind, particularly at sunrise, and more so in the months of January, February, March, October, and November than in other months of the year. The cessation of wind from May to September inclusive is comparatively rare; and, generally, throughout the year the absence of wind at 4 P.M., may be looked upon as unusual. In my records there are 1720 observations of "*No* wind," and 847 of these belong to sunrise, 452 to 9—10 A.M., and 304 only to 4 P.M.

The observations were continued through five years, three times daily; sunrise, 9—10 A.M., and 4 P.M. There is considerable uniformity in the direction of the wind in the same months in consecutive years. The westerly winds begin to *prevail* in March, alternating with easterly winds, which blow the latter part of the night; but the easterly winds disappear as the monsoon approaches, and do not re-appear again till October. In October the winds are variable, and the records of "No wind," increase suddenly and rapidly. A few easterly winds, however, about the end of the month, indicate the change which is to take place; they gradually increase, and with those from the N.E. and S.E., almost entirely supersede the winds from the westerly points during the cold months.

In March, from the sun's approach, the interior land during the day gets heated; an influx of air from the sea coast commences daily after 10 A.M.; but as the earth, at this period, cools more rapidly than the sea at night, the interior is cooler than the coasts, and there is a reflux of air towards the ocean; the easterly and westerly winds thus alternate day and night. This alternation, however, diminishes in the ratio of the sun's increasing power; and when the earth gets so thoroughly heated that it cannot reduce its temperature by radiation below that of the sea, the consequence is the prevalence of winds from the westerly points to the almost entire exclusion of those from easterly points. In June the westerly winds set in regularly. There are occasional instances of the wind blowing with much steady violence from the west for

many hours in the hot months with a sunny sky. In the early part of March some unaccountably cold winds, affecting vegetation even, have been known to blow.

Hot Winds.—The well-known hot winds of tropical continents do not prevail near the Ghàts; but the same wind, which is pleasant in their neighbourhood, may become a hot wind as it travels to Ahmednuggur and Arungabad. The east wind is characterized by its extreme dryness, and it is dangerous to sleep exposed to it.

Whirlwinds.—Those curious whirlwinds noticed by travellers in Africa, and which in the deserts are dangerous, are of common occurrence in Dukhun in the hot months. A score or more columns of dust, in the form of a speaking trumpet or waterspout, may be seen rapidly coursing over the treeless plains, marking a vortex of heated air. They are sufficiently powerful to unroof a thatched house, strike tents, and whisk away all light matters.

Hail Stones.—Hail stones of considerable magnitude sometimes fall in the thunder-storms of the hot months.

Dews.—Dews appear plentifully after the monsoon, and during the nights of the cold months; but their frequent local occurrence has often excited surprise.

Fogs.—Fogs are of so rare occurrence in the Desh, or country eastward of the Ghàts, that I have only nineteen records of them during five years. Along the Ghàts they are much more common; and during April and May, for three or four nights in the week, fogs drift rapidly to the eastward from the Konkun, or low country at the foot of the Ghàts. On some nights no drift takes place, and the fog remains resting on the Konkun; and, seen from the crest of the Ghàts at sunrise, has the appearance of a sea of milk. As the sun rises the fog creeps up the chasms of the Ghàts, and finally disappears by 10 A.M.

Salubrity of the Climate.—With respect to the salubrity of the open parts of the country, it will only be necessary to state that, in my little camp, consisting of more than a hundred souls (natives), I had not a single death of an adult during six years; nor a case of illness (excepting one) that I did not cure without regular medical aid. Dr. Walker, long civil surgeon in the city of Ahmednuggur, found the casualties in 1828 in that city (exclusive of losses from spasmodic cholera) to be only 1·82 per cent., or 1 in 55·1 persons; and, including cholera, 2·48 per cent., or 1 in 40·2 persons. Dr. Lawrence, in charge of a regiment of natives 1000 strong, lost only 0·85 parts of an

integer per cent. per annum, or about five men in 600 during the years the regiment was in Dukhun.

Parts of Khandesh have not credit for the same salubrity.

Botany.

Under this head I shall confine myself to a simple enumeration of the agricultural and garden products, and wild fruits. To enter into the botany of Dukhun generally would be misplaced in this digest. And first with regard to cultivated native fruits; they are forty-five in number, viz.

Cultivated Fruits.—Amba, *Mangifera indica*[a]; Oombur, *Ficus glomerata;* Phunnus, *Artocarpus integrifolia*[b]; Cheents, *Tamarindus indica*[c]; Ambarra, *Spondias Mangifera*[d]; Hurparewree, *Cicca disticha;* Ramphul, *Annona reticulata*[e]; Seetaphul, *Annona squamosa;* Raeebor, *Zizyphus jujuba;* Jamblee, *Calyptranthes caryophyllifolia;* Awlee, *Phyllanthus emblica;* Bail, *Ægle Marmelos*[f]; Wowulee, *Mimusops elengi;* Narlee, *Cocos nucifera*[g]; Jamb, *Eugenia Jambos*[h]; Mohha, *Bassia latifolia;* Toot, *Morus alba*[i]; Shatoot, *Morus indica*[k]; Choonchoo, *Morus* ———[l]; Kurumbul, *Averrhoa Carambola*[m]; Kuweet, *Feronia elephantum*[n]; Bhokur, *Cordia latifolia;* Anjeer, *Ficus Carica*[o]; Daleemb, *Punica granatum,* (two kinds)[p]; Weer, *Citrus limon*[q]; Chukotur, *Citrus decumanus*[r]; Maloong, *Citrus medica*[s]; Nareeng, *Citrus aurantium*[t], of these there are several kinds; Ambut neemboo, *Citrus acida*[u]; Sakur neemboo, *Citrus limon* var.[x]; Peroo, *Psidium Pyriferum*[y]; Peroo tambra, Red Guava; Kajoo, *Anacardium occidentale*[z]; Gondnea, *Cordia myxa;* Tarh, *Borassus flabelliformis;* Phopy, *Pupeea Carica;* Badam, *Terminalia catappa;* Sooparee, *Areca faufel*[aa]; Kujoor, *Phœnix dactilifera*[bb]; Kel or Kail, *Musa paradisiaca*[cc], there are several species or varieties. Sonkel, *Musa sapientum;* Draxhs, *Vitis Vinifera*[dd]. There are seven species of grapes in Dukhun, the Mahratta names of which are Kalee, or black; Ahbee, or watery; Phukree, or Muscadina; Saheebee, Bedana, or seedless; Sooltanee; and Suckree, or sugary. Khurbooz, *Cucumis Melo*[ee]; Phoot, *Cucumis momordica;* and Kulungrah, *Cucur-*

[a] Mango. [b] Jack fruit. [c] Tamarind. [d] Hog-plum. [e] Sweet-sop. [f] Bengal quince. [g] Cocoa nut. [h] Rose apple. [i] White mulberry. [k] Red mulberry. [l] Small mulberry. [m] Country gooseberry. [n] Wood apple. [o] The garden fig. [p] Pomegranate. [q] Lemon. [r] Shaddock. [s] Citron. [t] Orange. [u] Lime. [x] Sweet lime. [y] Guava. [z] Cashew nut. [aa] Betel nut. [bb] Date. [cc] Plantain. [dd] Grapes. [ee] Musk melon.

bita Citrullus[a]. There are several species or varieties of the melons.

Wild Fruits.—The wild fruits are twenty-two in number, viz. Beebah, *Semicarpus anacardium*[b]; Cher, *Chirongia sapida*; Ratambee, *Garcinia* ——[c]; Torun, *Zizyphus albens;* Kurwund, *Carissa Carandas* and *diffusa*, both of them excellent fruits; Seendee, *Phœnix Sylvestris*, or *Elate Sylvestris*[d]; Jungle Jaeephul, *Myristica dactyloides*[e]; Peempree, *Ficus comosa;* Rahbor, *Zizyphus Xylopyrus;* Bunkeil, *Musa troglodytarum*[f], two varieties; Gooloom, *Loranthus bicolor;* Lotowl, a genus and species not determined; Ambgoolee, *Elæagnus* ——, a very nice fruit, tasting like a gooseberry. Ulloo, *Vanqueria spinosa;* Temboornee, *Gardenia*, ——; Thurtee, *Capparis erythrocarpus;* Neptee, *Capparis aphylla;* Wagatee, *Capparis Zeylanica;* Makur Neembonee, *Citrus* ——[g]; Wuhr, *Ficus Indica;* Loheer, *Ficus* ——, a noble tree, 80 to 100 feet high.

The above comprise the wild fruits of Dukhun; many of them are not only passable, but very palatable, particularly the Ambgoolee, the Kurwund, and the Char. The Ratambee, or wild mangostein, is in extensive use as an acid seasoner, and is met with for sale in most markets in a dried state. The wild nutmeg is frequently imposed upon the ignorant for the real nutmeg. The oil of the Beebah is used for marking linen, like indelible ink; but the kernel roasted is agreeable. The wild lime (*Citrus*) is only met with in the Ghàts; it forms a handsome dense tree, but the cultivated fruit is so abundant that the wild is not made any use of. Many of the above fruit trees produce good timber. With respect to the mango, which is met with both cultivated and wild, it is considered by the people less as a luxury, than as an auxiliary to the necessaries of life, or as a substitute for them in seasons of scarcity; for the mango is in fruit, and seldom fails an abundant crop, at a time when the earth is parched up by the heats of May and beginning of June.

Agricultural Products.—A brief notice only of the agricultural products can be given. The harvests are of two distinct kinds: one is the Khurreef, or rainy season harvest; the other is the Rubee, or dry, or cold, or spring season, harvest.

Wet Season Harvest.—This harvest produces twenty-two kinds of grain and pulse; but the products of the Desh,

[a] Water melon. [b] The marking nut. [c] The wild mangostein.
[d] Wild date. [e] Wild nutmeg. [f] Wild plantain.
[g] The original apparently of some of the species of *Citrus* in Dukhun.

or open country, are different from those of the Mawuls, or hilly tracts along the Ghàts. The following are the products of the monsoon crop in the Desh: Jondla, *Andropogon Sorghum*, and of these there are many varieties; Sujgoora, *Panicum spicatum;* Rahleh, *Panicum Italicum;* Bhadlee, *Paspalum pilosum;* Kodroo, *Paspalum frumentaceum;* Mukka, *Zea Mays* [a]; Moog, *Phàseolus Mungo;* Ooreed, *Phaseolus radiatus;* Tooree, *Cytisus cajan;* Muht, *Phaseolus aconitifolius;* Teel, *Sesamum orientale*, two kinds; Ambaree, *Hibiscus Cannabinus;* Oolgeea, *Dolichos bifloris;* Waal, *Dolichos spicatus;* Rajgeerah, *Amaranthus oleraceus candidus;* Chuwluya, *Dolichos catiang;* and Gowarya, *Dolichos fabæformis*: there are thus seventeen products of the monsoon harvest of the Desh. The first six are bread grains, and are reduced to flour; Teel and Rajgeerah are eaten unground; Ambaree is a cordage plant, the rest are pulse, and are cooked in a variety of ways. Tooree is the universal substitute for the split pea of Europe; it is much more agreeable than the pea, and is more commonly used.

The produce of the rainy season harvest in the hilly tracts is Dhan, *Oryza sativa* [b], seventeen or eighteen kinds; Natchnee, *Eleusine coracana*, or *Cynosurus coracanus;* Sawa, *Panicum miliaceum;* Wuree, *Panicum miliare;* and, finally, Karleh, *Verbesina sativa*. All these require a superabundance of water. The rice, which is the chief support of the people of the hilly tracts, is sown in the valleys, because it can be constantly flooded. Karleh is an oil plant only; the others are sown on the sides of the mountains, in places inaccessible to the plough. They are either used whole, or are reduced to flour for bread. Rice is never reduced to flour.

It is not to be understood, that the above products, as separated into those of the hilly tracts and Desh, are rigidly confined to those tracts; where the physical circumstances permit of it, they are indiscriminately cultivated in both tracts. The returns of some of the above plants are prodigiously great. I have seen a plant of *Paspalum frumentaceum* with twenty stalks radiating from a common root, and with thirty-three spikes of grain, giving the astonishing return of 61,380 for 1; a single head of *Andropogon Sorghum* gave 2895 for 1; eight stalks of *Panicum spicatum* from a single root 16,960 for 1; and a single head of *Panicum Italicum* produced 1850 for 1!!

Dry or Spring Season Harvest.—The next harvest is that of the Rubee, or dry or spring season of the Desh. In this

[a] Indian corn. [b] Rice.

harvest, of twenty-three products, there are four species of fine wheat, viz. Guhoo Bukshee, *Triticum spelta;* Kupleh Guhoo, *Triticum* ——— *;* Kateh Guhoo, *Triticum* ——— *;* and Pohteeyai, *Triticum* ———, called bellied wheat, from the seed being very much swelled out in the middle. Urburee, *Cicer Arietinum;* Shaloo, *Andropogon saccharatum;* Juw, *Hordeum hexastichon*[a]; Watanah, *Pisum sativum*[b]; Kurdee, *Carthamus Persicus;* Juwus, *Linum usitatissimum;* Mohuree, *Sinapis racemosa,* and two other kinds; Taag, *Crotolarea juncea;* Yerund Tambra, *Ricinus communis*[c]; Yerund Eerwa, *Ricinus viridis;* Oos Tambra, *Saccharum officinarum*[d]; Oos Poonda, *Saccharum* ———[e]; Oos Pandra, *Saccharum* ———[f]; Oos Bèt, *Saccharum,* ———[g]; Shet Wallook, *Cucumis* ———, the literal meaning is field cucumber; Pawteh, *Dolichos* ———; Tumbakoo, *Nicotiana tabacum*; Shet Kapoos, *Gossypium herbaceum*[h]; Bhoeemoong, *Arachis hypogæa*[i].

The above are chiefly produced in the Desh, in the dry season. Urburee, *Cicer arietinum,* is the universal substitute for oats for horses; and, excepting in the rains when green grass is obtainable, the juicy, sweet, and nutritious stalks of the Shaloo, *Andropogon sorghum,* and varieties, is their only forage. Oil is expressed from the seeds of Kurdee, Juwus, Mohuree, and Yerand. Juwus is not used for its flax. Although there are four kinds of sugar-cane, and much raw sugar is produced, the processes of refining are not carried on. The bark of Taag is used for ropes and coarse canvas. The returns from the wheat are very considerable; I have a specimen of Kupleh Guhoo, with twenty-five stalks from one root, giving a return of 1450 for 1; ten stalks are very common; a specimen of the Kateh Guhoo, also in my possession, with fifteen stalks from a single root, giving a return of 480 for 1. The average on tolerable land is eight stalks or ears to a plant. The tobacco from some parts of the country is reckoned very fine.

The dry season harvest of the hilly tracts is almost entirely confined to Mussoor, *Ervum hirsutum;* and Pawta, a variety of *Dolichos Lablab.*

Garden produce.—The produce of the gardens is of great importance to the natives of India, from their poverty limiting them very much to a vegetable diet, corrected by aromatic seeds and condiments. Most of the plants cultivated in the

[a] Barley. [b] Peas. [c] Castor oil. [d] Red sugar cane.
[e] Variegated sugar cane. [f] White sugar cane. [g] Reed-like sugar cane.
[h] Field cotton. [i] The earth nut.

gardens of the Desh are also produced in the gardens, where they exist, (which is rarely) of the hilly tracts. The products are forty-six in number, viz., Dhunya, *Coriandrum sativum*[a]; Mehtee, *Trigonella fœnugrecum;* Shepoo, *Anethum sowa;* Bureeshep, *Anethum fœniculum*[b]; Wowa, *Ligusticum agivaen;* Hulwee, *Lepidum sativum;* Meerchya, *Capsicum annuum*[c]; of this there are many species. Patee, *Allium cepa*[d], red, white, and yellow; some of which are so mild as to be used as vegetables. Chakweet, *Chenopodium album;* Chooka, *Rumex Vesicarius*[e]; Wahlea, *Basella rubra* and *alba;* Aaloo, *Arum campanulatum;* Tandoolja, *Amaranthus polygamus;* Maat Tambree, *Amaranthus oleraceus,* Var.; Paluk, *Beta Bengalensis;* Mohtee gohl, *Oxalis monadelphus;* Gohl, *Portulaca oleracea;* Pokulla, *Amaranthus, ——;* Poodna, *Mentha viridis;* Chundun Butwa, *Chenopodium, ——;* Bhang, *Cannabis sativa*[f]; and Nagwail, *Piper Betel.* The most valuable of the above plants produce aromatic or pungent seeds; most of the rest are pot-herbs held in considerable estimation.

Edible roots.—The next division of garden produce is denominated Mool Bojee, which literally means "root-greens," properly edible roots. Mooleh, *Raphanus sativus*[g]; Rutalee, *Convolvulus batatas*[h]; Kohn, *Dioscorea purpurea* or *alata*[i]; Gajur, *Daucus carota*[j]; Lussoon, *Allium sativum*[k]; Soorun, *Arum, ——;* Rungeh, *Dioscorea fasciculata;* Alluh, *Amomum Zingiber*[l].

Fruit vegetables.—A further division is made of Phul bajee or fruit greens, which means fruits eaten as vegetables, viz., Bhendee, *Hibiscus esculentus;* Wangee, *Solanum melongena*[m], several species or varieties; Gewree, *Dolichos, ——;* the seeds are eaten as pulse, and there are several varieties; Dorkee, *Cucumis acutangulus;* Gosaled, *Luffa pentandria;* Karlee, *Momordica Charantia;* Tondlee, *Momordica monadelphia;* Purwal, *Trichosanthes anguina;* Purwar, *Trichosanthes cucumerina;*[n] Turkakree, *Cucumis usitatissimus;* Kateh Wallook, *Cucumis sativus,* warty, prickly cucumber; Doodh Boplah, *Cucurbita longa;* Boplah-tambra, *Cucurbita Pepo,* red pumpkin; specimens of this fruit are sometimes more than eighteen inches in diameter; Kohwall, *Cucurbita alba;* Dhendsee, *Cucurbita, ——;* Kasee Boplah, *Cucurbita lagenaria.*

Such are the cultivated garden products of the natives: it will be seen that they are rich in the cucurbitaceous family,

[a] Coriander. [b] Sweet fennel. [c] Chilly. [d] Onions.
[e] Blister sorrel. [f] Hemp. [g] Radishes. [h] Sweet potatoe.
[i] Yam. [j] Carrots. [k] Garlic. [l] Ginger. [m] Egg plant.
[n] Common cucumber.

and not less so in the aromatic and pungent plants; and the edible roots are various. Edible leaves, used as greens, are very numerous, particularly those produced spontaneously. My limits do not permit me to give even the names of wild plants producing greens, fruits used as vegetables, or edible roots; the flowers of some plants are used as greens; such as the Angustee, *Æschynomene grandiflora;* the Shewga, *Hyperanthera morunga*, or horse-radish tree; and those of the Kanchun, *Bauhinia purpurea;* the foot-stalks of the flowers of the splendid *Convolvulus candicans* are used in a similar way. The tender twigs of the common bamboo are good as greens, and they are also made into a pickle. The flower, stalks, and roots of the Lotus (*Nympha esculenta*) are reckoned fine; but I must stop.

Grasses.—The grasses are innumerable, and are not less distinguished for their beauty than their variety. One of the most common is that highly nourishing grass the *Agrostis linearis*, which, it appears, is a native of Cornwall, under the name of *Panicon dactylon.* In biting the knots or joints of the Ghateea (*Andropogon Martini?*) there is a strong, pungent, aromatic, and oleaginous exudation. The well-known aromatic Khus Khus (*Andropogon muricatus*) is abundant in Dukhun, as well as the sacred grass Durb, *Poa cynosuroides.* In speaking of the grasses it may be as well to say that it is not the practice of the natives to make hay from meadows; they allow the grass on waste lands to become perfectly dry, and then cut it down with the sickle, as a substitute for hay.

Wild cordage plants.—The spontaneous cordage plants are the Gayal, *Agave vivipara;* the Kaswuree, *Sida patens;* and some others.

Wild oil plants.—The wild oil plants are the Kurunj, *Galedupa arborea*; and the Kurd Kangonee, a small tree of the class and order *Pentandria monogynia.*

Wild tanning plants.—The plants used in preparing leather are the Chambar Heerda, *Terminalia Chebula;* Rahn Turwur, *Cassia auriculata;* the Sadrah or Aaeen, *Terminalia alata glabra;* and the Baubul, *Mimosa arabica*, the bark of which is in great repute.

Medicinal plants.—The medicinal plants are numerous. Amongst the most useful are the Khyr, *Mimosa catechu;* the Seegeekaee, *Mimosa abstergens;* many species of *Datura;* Kuntuh Kareeka, *Solanum jacquini;* Sagurgotta, *Cæsalpinia bonduccella;* Korpur, *Aloe succotrina;* Dadmaree, *Euphorbia tirucalli;* Gooleea Eendrawun, *Cucumis colocynthis;* Reeta, *Sapindus detergens;* Sahl Phul, *Boswellia thurifera;* Baw-

cheea, *Psoralea corylifolia;* some of the *Ocimums,* and many of the *Asclepias* family. Of the powerfully scented plants, the *Michelia Champaca,* (Champa), *Pandanus odoratissimus,* several species of Jasmine, Polyanthus, Rose, &c., abound.

European fruits.—Very few of the European fruits are cultivated in Dukhun; indeed, those produced are almost confined to peaches and strawberries, both of which are as fine as in Europe. All the European vegetables thrive, such as cauliflowers, cabbages, asparagus, spinach, and broccoli. Potatoes, when properly attended to, are also good. Carrots, turnips, and radishes are indigenous.

Flowering plants.—It is not within my present view to attempt an enumeration of the wild flowering plants of Dukhun, many of which are splendid and curious. Nothing can exceed the magnificence and beauty of the vegetation in the Ghàts during the monsoon. The brilliancy of the *Erythrinæ,* the *Cassiæ* (particularly the *Cassia fistularia,*), the lofty *Bombax,* the varieties of the *Liliaceæ, Cannæ, Convolvulaceæ,* and *Malvaceæ,* would surprise and delight a European florist.

In the Desh, the dwarf *Cassia auriculata,* with its numerous yellow flowers, enlivens the whole country; and the numerous species of *Mimosa* (particularly the *Mimosa odoratissima*), perfume the air.

The Dukhun produces few ferns and no heaths, and none of the coniferous family, excepting *Cupressus;* the Musci (true mosses) are rare; there are many of the *Euphorbiaceæ;* no oaks, elms, or hazels, or indeed any of the *Amentaceæ,* excepting *Salix tetrasperma;* multiplied genera and species of the *Jasmineæ, Labiatæ, Compositæ, Umbelliferæ, Leguminosæ,* and *Cucurbitaceæ;* the *Cruciferæ* are not abundant; but the *Capparides* are very much so. The rosaceous plants are rare; but the *Solanaceæ* (*Luridæ*) are very abundant; although the potatoe is not indigenous.

Such is the meagre sketch of the botany of Dukhun; for the elaboration of which there are abundant materials at the India House, in a Hortus Siccus collected by myself.

I must not omit to notice that the Sandal-wood tree, *Santalum album,* is met with, both in the cultivated and wild state.

Timber trees.—The Warsa, *Bignonia quadrilocularis;* the Tamarind, *Tamarindus Indica;* the Jack, *Artocarpus integrifolia;* and the *Bauhineæ,* produce excellent wood for furniture; and all the species of *Mimosa* furnish hard durable wood for tools and machinery.

Zoology.

Like the account of the botany, the zoology must be con-

fined to little more than a mere catalogue of the beasts and birds of the country.

The inhabitants of Dukhun have the Georgian form of skull: their stature is low, but not very slender; the colour of the skin is brown, with shades running into yellow and white in the higher classes, and black in the lower; the females are not distinguished for beauty or fertility, the average number of births to a marriage being less than in Europe; more males are born than females, and, unlike Europe, they preponderate through all periods of life.

Quadrumana.—Of the monkey tribe I met with only two kinds, *Semnopithecus Entellus* and *Macacus radiatus.* A new species described by me, *Cercopithecus albogularis,* was not from Dukhun.

Cheiroptera.—Three species of bats, Wurbagool, *Pteropus medius; Nyctinomus plicatus;* and *Rhinolphus Dukhunensis.*

Plantigrada.—Chuchoondur, *Sorex Indicus,* or musk-rat; Aswail, *Ursus labiatus,* or labiated bear; Juhl Manjur, *Lutra Nair,* otter.

Digitigrada.—Of these animals, the first is the Kolsun or wild dog, *Canis Dukhunensis,* which was first described and brought to Europe by myself; Landguh, *Canis pallipes,* wolf, a new species; Kholah, *Canis aureus,* jackal; Kokree, *Canis Kokree,* a new species of fox; of the *Viveridæ,* the Juwadee Manjur, *Viverra Indica* or civet cat of Dukhun; Moongus, *Herpestes griseus,* Mungoose; Ood, *Paradoxurus Typus.* The *Hyæna, Turrus* of the Mahrattas, *Hyæna vulgaris,* is common in Dukhun, and is capable of domestication like a dog. The *Felinidæ* are numerous, not only in individuals, but in species, excepting the lion, which is not met with. Puttite Wagh, *Felis tigris,* royal tiger; Cheeta, *Felis leopardus* or genuine leopard, is rare; but the Beebeea Wagh, or panther, *Felis Panther,* is most abundant. Cheeta, *Felis jubata,* or hunting leopard, is common. Mota Rahn Manjur, *Felis chaus;* Lhan Rahn Manjur, *Felis torquatus,* or lesser wild cat; the preceding being considered the larger wild cat. The species of the genus *Felis* here terminate. Of the rat family there is the Ghoos, *Mus giganteus,* or Bandikoot rat; Chooa, *Mus decumanus,* or Norway rat; *Mus musculus,* the mouse; and a very pretty field mouse of a bright chestnut colour, which is a new *Mus oleraceus,* also a second new mouse, *Mus platythrix.* Of the squirrel family there are only two species; the first, a splendid animal as large as the *Sciurus maximus,* of a chestnut colour, with a whitish tail; I have called it *Sciurus Elphinstonii,* the Mahratta name is Shekroo: the other species is the Khurree, or *Sciurus palmarum.* The porcupine, Sayal,

is a new species, which I have called *Hystrix leucurus*. The hare, Sussuh, which abounds in Dukhun, is the *Lepus nigricollis* of F. Cuvier. That very curious animal, the Pangolin, *Manis crassicaudata*, is common; the Mahrattas call it Kuwlee Manjur, or tiled cat, the scales being imbricated as tiles on the roof of a house. The Dookur, or wild hog, *Sus scrofa*, abounds: every village also has a number of tame hogs, which are the public scavengers, but all property in them is abjured by the inhabitants. The Dukhun is celebrated for a breed of fine horses with a dash of the Arabian blood in them: the pony also is bred to a great extent to carry baggage. The Ass, Gudha, *Equus asinus*, is not much larger than a good-sized Newfoundland dog; it is not met with in the wild state.

Ruminantia.—The Dromedary, Oont, *Camelus dromedarius*, is rarely bred in Dukhun, but is in general use; the two-humped camel is unknown. Of the other Ruminants, the first is a beautiful little creature called Peesoreh, *Moschus memina;* the next is the Sambur, *Cervus equinus*, of the size of a small cow; the third is the Baikur, *Cervus muntjak:* all the above are inhabitants of dense woods. Of the antelopes there are four species; Bahmunee Hurn, *Antilope cervicapra;* Kalesepee, or black tail, a new species, *Antilope Bennetti; Antilope quadricornis;* and finally, the Rooee, *Antilope picta*, or Nylgau: the two former are only found on the open plains; the two latter prefer the woods, but are sometimes seen on the plains. Goats, Bukree, *Capra hircus*, abound; and sheep are so extensively bred in Dukhun, that flocks of many thousands are constantly met with grazing on the uncultivated lands; the wool is coarse and crisp; the price of a sheep is from two to four shillings; they afford excellent, although small mutton. The Pohl is the Brahmany bull, with its remarkable hump, *Bos taurus* var. *Indicus*, and is a noble animal; when put into the yoke, or when employed in carrying loads, he is called Byhl, and he loses his hump and his fine appearance. The cow does not yield much milk. Cattle are extensively bred, as it is chiefly by their means the transit of merchandize is effected. The female buffalo, Muhees, *Bos bubalus*, is highly valued for the quantity of milk she gives. The male, called Tondgah, is used in the hilly tracts in ploughing the muddy fields for rice. The above is the catalogue of the *Mammalia* of Dukhun, and a few comments will suffice respecting it. The musk-rat is a pest, from its infecting with its nauseous odour everything with which it comes into contact, even a bottle of wine, although corked. The bear is harmless. The wild-dog hunts in troops in the

woods, and runs down the fleetest of the ruminants. The wolves sometimes attack women and children, but never men. The jackals are in large troops, and do much damage in the vineyards. The fox is mostly solitary or in pairs. The moongus is useful in destroying snakes. The hyæna is cowardly, entirely nocturnal in his movements, and never attacks live animals. The royal tiger and the leopard are formidable to man and beast; but the people consider themselves safe against the attacks of the panther and smaller cats, when armed with a good stout stick. The *Mus giganteus* undermines buildings. Of the rest of the wild animals it is not necessary to say more, than that they, like those just enumerated, are most of them objects of the chase with the Mahrattas, who are capital horsemen, and many of them keen sportsmen.

Birds.—The birds are very numerous; many of them not less useful to man, than agreeable from their plumage. Song-birds are, however, rare. My catalogue contains 232 species of the several orders, families, and genera.

Raptores.—There are 13 genera of the first order Raptores,—*Vultur Indicus, Vultur Ponticerianus, Vultur Bengalensis, Neophron Percnopterus, Haliaëtus Ponticerianus, Circaëtus brachydactylus, Aquila chrysaëta, Aquila bifasciata, Hæmatornus Bacha, Accipiter Dukhunensis, Accipiter Dussumieri, Astur Hyder, Falco Tinnunculus, Falco Chicquera, Circus pallidus, Circus variegatus, Milvus Govinda, Otus Bengalensis, Strix Javanica, Strix Indranee, Ketupa Leschenaulti,* and *Noctua Indica.* Of the above order there are two new *Accipiters,* one new species of *Circus,* one *Milvus,* and a *Strix.* The *Neophron* is the Ractamah of Bruce, the sacred vulture of the Egyptians, and it is a most useful scavenger, removing all offal matters. The golden eagle is the same as that of Europe, and so is the *Falco Tinnunculus;* and the harriers are scarcely distinguishable from the European birds. The falcons, hawks, and goshawks, are used by the natives in hawking.

Insessores.—There are 53 genera, and 116 species of the order *Insessores.* Few or none of these can be said to be useful to man, and only two of the species are songsters:—*Merops viridis, Hirundo filifera, Hirundo Jewan, Hirundo concolor, Hirundo erythropygia, Cypselus affinis, Caprimulgus monticulus, Caprimulgus Asiaticus, Caprimulgus Mahrattensis, Halcyon Smyrnensis, Alcedo rudis, Alcedo Bengalensis, Ceyx tridactyla, Muscipeta Paradisi, Muscipeta Indica, Muscipeta flammea, Muscipeta peregrina, Muscicapa melanops, Muscicapa Banyamus, Muscicapa Poonensis, Mus-*

cicapa cœruleocephala, Muscicapa picata, Rhipidura albofrontata, Rhipidura fuscoventris, Dicrurus Balicassius, Dicrurus cœrulescens, Hypsipetus Ganeesa, Collurio Lahtora, Collurio erythronotus, Collurio Hardwickii, Lanius Muscicapoides, Graucalus Papuensis, Ceblepyris fimbriatus, Ceblepyris canus, Oriolus galbula, Oriolus melanocephalus, Oriolus Kundoo, Turdus macrourus, Turdus Saularis, Turdus cyanotus, Petrocincla Pandoo, Petrocincla Maal, Petrocincla cinclorhyncha, Timalia Malcolmi, Timalia Somervillei, Timalia Chatarœa, Ixos jocosus, Ixos cafer, Ixos fulicatus, Pomatorhinus Horsfieldii, Iora Tiphia, Sylvia montana, Sylvia sylviella, Sylvia Rama, Prinia socialis, Prinia inornata, Orthotomus Bennettii, Orthotomus Lingoo, Budytes citreola, Budytes melanocephala, Budytes Beema, Motacilla variegata, Motacilla Dukhunensis, Megalurus ruficeps, Anthus agilis, Saxicola rubicola, Saxicola bicolor, Saxicola rubeculoides, Saxicola erythropygia, Phœnicura atrata, Phœnicura Sueciea, Parus atriceps, Parus xanthogenys, Alauda Gulgula, Alauda Deva, Alauda Dukhunensis, Mirafra phœnicura, Emberiza melanocephala, Emberiza hortulana, Emberiza cristata, Emberiza subcristata, Linaria Amandava, Ploceus Philippensis, Ploceus flavicollis, Fringilla crucigera, Lonchura nisoria, Lonchura cheet, Lonchura leuconota, Passer domesticus, Pastor tristis, Pastor Mahrattensis, Pastor roseus, Pastor Pagodarum, Corvus culminatus, Corvus splendens, Coracias Indica, Buceros, several species, *Palœornis torquatus, Palœornis melanorhynchus, Bucco Philippensis, Bucco caniceps, Picus Mahrattensis, Upupa minor, Leptosomus Afer, Eudynamys orientalis, Cuculus canorus, Cuculus fugax, Centropus Philippensis, Chloropsis aurifrons, Cinnyris lepida, Cinnyris currucaria, Cinnyris Vigorsii, Cinnyris minima, Cinnyris Mahrattensis,* and finally, *Cinnyris concolor.* The above catalogue requires very few observations. The weaver-bird, *Ploceus Philippensis,* is remarkable for its pendent nest, woven in the most curious and ingenious manner from fibres of grass. Not less curious are the nests produced by the tailor-birds, the *Prinia socialis* and the *Orthotomus Bennettii,* which sew leaves together to inclose their nests, with the skill of a veritable knight of the thimble. The lark, *Alauda Gulgula,* has the habits and delightful song of the skylark of Europe; and two or three species of the genera *Budytes* and *Motacilla* have sweet notes: the *Collurio Lahtora* has also a sweet note. The *Muscipeta Paradisa* and *Indica* are distinguished for their beautifully elongated tail-feathers. The *Coracias Indica* is characterized by its splendid colouring; and not less so is the *Cinnyris Vigorsii.* The cuckoo is the identical

bird of Europe, and so is the sparrow. In the above list I have named many new species of *Insessores*, and have introduced one new genus.

Rasores.—That order so highly useful to man, the *Rasores*, does not contain one single species in Dukhun that is not valuable as an article of food. There are 12 genera and 40 species. *Ptilinopus Elphinstonii, Columba mœna, Columba tigrina, Columba humilis, Columba rasoria, Columba Cambayensis, Columba Ænas, Meleagris Gallopavo, Pavo cristatus, Gallus giganteus, Gallus Sonneratii, Gallus domesticus, Gallus morio, Gallus crispus, Numida Meleagris, Coturnix dactylisonans, Coturnix textilis, Coturnix Argoondah, Coturnix Pentah, Coturnix erythrorhyncha, Perdix picta, Francolinus Pondicerianus, Francolinus spadiceus, Pterocles exustus, Pterocles quadricinctus, Hemipodius pugnax, Hemipodius Taigoor, Hemipodius Dussumier, Otis nigriceps*, and *Otis fulva*. Of the above, Turkeys and Guinea fowls are not indigenous, and it may be doubted whether the gigantic cock be a native. The original of the domestic fowl is most abundant in the woods of the Ghàts. The real partridge, *Perdix picta*, is found in the valleys of the Ghàts. What is usually denominated a partridge in Dukhun, is the *Francolinus Pondicerianus;* it is numerous, and affects cultivated lands and garden grounds. The common quail of Europe is a native of Dukhun; and three new species, which I have described, as well as the *Coturnix textilis*, literally swarm. That noble bird the *Otis nigriceps* is met with in large flocks, and the floriken is by no means scarce.

Grallatores.—Of the fourth order, *Grallatores* or Waders, there are 25 genera and 46 species, and very many of the species are common to Europe. *Grus Antigone, Ardea Egretta, Ardea Garzetta, Ardea Asha, Ardea cinerea, Ardea nigrirostris, Ardea Malaccensis, Ardea Caboga, Ardea Grayii, Ardea Javanica, Ardea cinnamomea, Botaurus stellaris, Nycticorax Europæus, Phœnicopterus ruber, Platalea leucorodia, Platalea junior, Ciconia leucocephala, Ciconia Argala, Anastomus Typus, Tantalus leucocephalus, Ibis religiosa, Ibis ignea, Ibis papillosa, Ibis falcinella, Totanus ochropus, Totanus Glareola, Totanus hypoleucos, Limosa Glottoides, Limosa Horsfieldii, Gallinago media, Gallinago minima, Rhynchea picta, Pelidna Temminckii, Parra Sinensis, Gallinula Javanica, Rallus Akool, Porphyrio Smaragnotus, Fulica atra, Cursorius Asiaticus, Vanellus Goensis, Vanellus bilobus, Charadrius pluvialis, Charadrius Philippensis, Himantopus melanopterus*, and *Œdicnemus crepitans*. Of the above, the *Ibis religiosa* is undoubtedly the sacred or

mummy *Ibis* of the ancient Egyptians, according to Cuvier's description. The species of the family of the *Ardeidæ* are varied and beautiful. The snipes are those of Europe, as well as most of the species of the *Scolopacidæ*, and some of the *Rallidæ*.

Natatores.—The last order, *Natatores* or swimmers, contains 13 genera and 20 species, and, as in the preceding order, several of the species are common to Europe. *Plectropterus melanotus, Anser Giria, Tadorna rutila, Anas strepera, Rhynchaspis virescens, Mareca pœcilorhyncha, Mareca fistularis, Mareca Awsuree, Querquedula Circia, Querquedula Crecca, Fuligula rufina, Fuligula* ——, *Fuligula cristata, Podiceps Philippensis, Phalacrocorax Javanicus, Plotus melanogaster, Sterna acuticauda, Sterna similis, Sterna Seena,* and *Viralva Anglica.* The geese, ducks, and teals abound most in the cold season, and are at that period excellent eating. The domestic goose and duck of Europe is not included in the above list, but both are extensively bred in Dukhun. That rare English bird the *Viralva Anglica* is very common in Dukhun. I did not meet with the Pelican, although it is a native of India.

Ichthyology.—The rivers of Dukhun abound with fish, and some of them are not only palatable, but very fine flavoured, particularly the Tambra, a new species of *Cyprinus*, and the Waam, *Macrognathus armatus*; the Singhala or *Pimelodus* is also in very general use by the people, but is not esteemed by Europeans. The fish observed by me consisted of forty-six species; two belonged to the sub-order *Apodes*, three to *Thoracici*, and forty-one to *Abdominales.* The whole were comprised in twelve genera. There was one *Murena*, one *Macrognathus*, one *Chanda*, one *Ophiocephalus*, one *Gobius*, two species of *Silurus*, nine of *Pimelodus* and sub-genera, one *Ageneiosus*, one *Mystus*, twenty-four of *Cyprinus* and sub-genera, one *Essox*, and three species of *Cobitus.* It is remarkable that the fresh water *Essox* of Dukhun so closely resembles the salt water species of England, as to be scarcely distinguished from it, not only in external characters, but in the colour of its bones.

Reptilia.—Reptiles are numerous in Dukhun. The *Trionyx Indica* abounds in the rivers, and there are two smaller species. Many genera of the Saurian family are met with from the four to five feet *Monitor*, to the minutest *Lacerta.* Serpents of all kinds, from the gigantic Boa Constrictor to the small and beautiful carpet snake. The first, however, I have only seen carried about the country by people who exhibit

the feats of the reptile in swallowing small animals. Independently of the deadly *Cobra da Capello*, (*Coluber Naag*) there are some other poisonous species, but in general the snakes are harmless.

Crustacea.—Of the *Crustacea*, I shall have only to notice the Kenkra, *Thelphusa cunicularis*, a new species which pervades the valleys and table-lands of the Ghàts, and whose numbers are so great that their burrows riddle the earth; they remain quiet in their holes during the cold and dry seasons, but, in the monsoon, they are abroad in such numbers, that travellers drive over them, ride over them, and trample upon them in the high roads: they are not an article of food with the natives, but are, I believe, wholesome.

Testacea.—There are some few genera and species of land and fluviatile shells, the largest of which is a *Unio;* but they do not call for notice.

Entomology.—Like all tropical climates, the Dukhun teems with insects. The domestic fly is a pest at certain seasons; the most rigid precautions and the greatest cleanliness cannot secure the most fastidious person from the inroads of the bed-bug; and there is no getting beyond the "*maximum leap of a flea*"; the fact is, these plagues are not only the constant companions of the people, but the flea inflicts serious injury on poultry, dogs, and cattle. Domestic, and indeed wild animals are subject also to the attacks of a small blue tick, (*Acarus*,) which multiplies upon them in such an incredible manner as to affect the vital functions and produce paralysis and death. There are three species of honey-bee in Dukhun, the honey from the whole of which is remarkably fine. It boasts also its lac insect, *Coccus laccus;* and several silk-producing moths, particularly the Kolesurra, *Bombyx Paphia*.

The most destructive of the insect tribe is the white ant, *Termes*, which, working under cover with the most indefatigable perseverance, finds its way everywhere, and everywhere occasions loss and injury; books, papers, clothes, leather, wood, &c., are indiscriminately devoured. Several species of genuine ants are also a great nuisance. A species of sphex makes its earthen nest within the locks of the doors, and blocks up the key-holes. The musquito, *Culex*, is not quite so troublesome in Dukhun as on the coast. The scorpion, of which there are two or three species, so abounds in the stony lands of Dukhun, that on encamping my regiment, on the march from Punderpoor to Ahmednuggur in 1818, I had from two to three hundred brought to me in the course of a day by my men: their sting produces intolerable pain for

a few hours, but is not dangerous unless to the diseased and weakly. The centipede does not attain the growth of its type in South America, nor is it very numerous.

As in other countries, the *Coleopterous* order is the most numerous. Some of the genera are remarkable for their habits, (*Copridæ*,) and some are remarkable for their beauty (*Buprestidæ*). Amongst the *Lepidoptera* many are very handsome, both in the diurnal and nocturnal families (*Papilio Hector* and *Bombyx Atlas*). In the *Hemipterous* order, the *Cimicidæ* abound, and are cursed with all imaginable abominable smells. In the order *Orthoptera*, the *Gryllidæ* are numerous; but the locust is unknown as a scourge. In this order also, the multiplied and strange forms of the *Mantis* and *Phasma* are very striking. The *Blatta* is troublesome and injurious. The *Hymenoptera* includes some valuable and interesting genera. Of the *Apterous* insects I have already spoken. The *Neuroptera* are both numerous and beautiful, some of the *Libellula* and *Myrmeleons* particularly so. Of the *Diptera*, the genera *Musca*, *Culex*, *Bombilius*, *Hippobosca*, and *Tipula*, exhibit the greatest number of species and individuals. In *Arachnida* the genera are endless. The prevalence of scorpions I have spoken of.

Civil Divisions.

The British territories in Dukhun are divided into four collectorates, Poona, Ahmednuggur, Dharwar, and Khandesh or Candeish. Over each of these there is a European civil servant of the Company, with several European assistants, for the purpose of collecting the revenue. These gentlemen are armed with magisterial powers, and can call upon the military authorities for assistance. These collectorates are divided into Talooks (great divisions), provinces, Pergunnahs (counties), and Turrufs (hundreds);* and native officers called Mamlutdars, aided by inspectors of cultivation, accountants, treasurers, and a police force, are placed over one or more Pergunnahs. All these terms are of Moosulman introduction; the ancient Hindoo civil officers being differently named, and their territorial divisions were Prànt, Deshmookee, and Naikwaree. The aggregations of habitations are called Sher (city), Kusbeh (market-town), Mouzeh or Gaòn (village), and Waree (hamlet). The cities and towns may comprise several villages, and they have their suburbs called Peit. The village constitution is noticed under land tenures.

* Provinces, counties, and hundreds are not the exact equivalents of the native territorial divisions, but they afford sufficiently approximate types.

Poona Collectorate.—The Poona Collectorate is the nearest of the four collectorates of Dukhun to Bombay: its boundaries towards the coast approach within about fifty miles of that presidency, but they do not descend the Ghàts into the strip of land at the foot of the Ghàts, called the Konkun (Concan). This collectorate has an area of 8281 square miles, including the lands held in military tenure (Jagheer). It contains 550,313 inhabitants, 1897 towns* and villages, and 114,887 houses; averaging 66·45 inhabitants to a square mile, 4·79 to a house, 247·36 to a village, exclusive of the population of Poona. The chief town is Poona, recently the capital of the Mahratta empire, containing a population of 81,315 souls. The other principal towns are Tullegaon (2050 males, 2007 females), Joonur (4218 males, 3759 females), Kheir (1999 males, 1794 females), Goreh (1154 males, 1145 females), Ootoor (2521 males, 1928 females), Narraingaon (1286 males, 1180 females), Alley (1396 males, 1064 females), Sassor (1880 males, 1696 females), Jeejooree (885 males, 860 females), Tullegaon, *Turruf Paubul* (1710 males, 1427 females), and some others; but the most populous of the number, as is seen above, contains only 7977 souls. There are, excluding Sholapoor, 8 pergunnahs and 32 turruffs in the Poonah collectorate. In Sholapoor sub-collectorate there are 4 talooks, 19 pergunnahs, and 12 turruffs; but as divisions which in the other collectorates are called turruffs, are here called pergunnahs, there are few turruffs. My limits will not permit of detailed descriptions of these pergunnahs, although there are many physical facts of interest connected with some of them.

The following number of towns and villages constitute the different pergunnahs and talooks: Sewnere 190, Indapoor, 86, Kheir 236, Pabul 65, Poorundhur 130, Beemthuree 92, Hawailee 165, the Mawuls 233, Sholapoor 122, Mohol 145, Indee 236, and Moodebehal 226. This makes a total of 1926, which is 29 villages more than was previously stated, but this is owing to depopulated villages being included; of this 1926, 47 towns and 1429½ villages belong to the British; 4 towns and 264½ villages are held in free gift (Eenam), and 3 towns and 178 villages are held on tenure of military service (Surinjam).

Hill forts.—In the Poona Collectorate are situated many remarkable hill forts, impregnable in fact if properly defended, from their geological structure, which consists of beds of basalt, with vertical edges, alternating with beds of amyg-

* Trifling transfers have taken place between the different collectorates, so that this may not be the exact amount at the present moment.

daloids, whose edges form a talus. Many of these in their superficial plane manifest a strong disposition to a trigonal character. Such is the case with Teekonee (the word being almost Greek,) or three-angled, Koaree, and some others. Koaree is situated at the edge of the Ghàts in the civil division called the Powar Khoreh; its summit is 2910 feet above the sea; and some parts of the rock within its area are so powerfully magnetic, as to draw the needle quite round the compass. The hill forts of Singhur, Poorundhur, and Wuzeerghur are seen from Poona: the summit of the first is elevated 4192 feet above the sea, and the second 4471 feet. The hill-fort of Sewnair, in which the celebrated Sewajee was born, is situated close to the city of Joonur (Jooneer). Jewdun, is on the edge of the Ghàts, a few miles westward of Joonur, and Hurreechundurghur, which is said to be eighteen miles in circumference at its base, is situated a few miles N.W. of Joonur. But I have not space to enumerate all these points of defence provided by nature,—Loghur, Eesapoor, &c. &c.

Boodh cave-temples.—Some works of art must not be overlooked. The first is that magnificent cave-temple situated in the civil division called Naneh Mawul; it is usually denominated the cave of Karleh (Carlee), from being within two miles of a village of that name; the temple is associated with many cave-chambers. The other Boodh excavations are pierced in the hills around the city of Joonur, under the hill-fort of Joonur, and at the crest of the pass into the Konkun from Joonur, called the Naneh Ghàt. Numerous inscriptions, in so antique a form of the Sanscrit alphabet as not to be readable by modern Sanscrit scholars, abound in these caves.* These astonishing works of art, resulting from the labour of ages, and which are met with, not only in the Poona Collectorate, but in many other parts of India, would seem to indicate that the country was once inhabited by a Boodhist population, although it has so entirely disappeared, that not a solitary worshiper of Boodh remains in the peninsula of India.

In the Under Mawul, at the village of Mhow, there is an extraordinary large Wuhr-tree (*Ficus Indica*); it has sixty-eight stems, most of them thicker than a man's body, and, with the exception of the original stem, the whole of them originate in roots let down from the branches; it was capable of affording shade, with a vertical sun, to 20,000 men, being 201 feet long by 150 feet broad. At the town of Mun-

* Within the last year, those indefatigable and learned orientalists, Principal Mill, Mr. James Prinsep, and Mr. Stevenson have succeeded in reading most of the inscriptions which are found to relate exclusively to Boodhism and Boodhists.

chur, in the pergunnah of Pabool and Turruf Wurgaon, there is a Baubel-tree (*Mimosa Arabica,*) of surprising magnitude; at eighteen inches from the ground the trunk measures nine feet and half an inch in circumference; its head is ramous and dense, and it gives a vertical shade covering 5964 square feet: this species produces gum arabic. In the turruf of Chakun, pergunnah Kheir, near to Mahloongah, on the slopes of some hills, the shrub or small tree, producing the gum olibanum, (*Boswellia thurifera*), is met with; and it is seen also in other parts of the country. At Mahloongah there is a garden of flourishing cocoa-nut trees; and considering that they are at 2000 feet above the sea, and 100 miles inland, the fact is sufficiently remarkable: clumps of them are also met with at Pabool and other places.

Rivers.—The rivers flowing through the Poona Collectorate are the Mota, the Mola, the Inderanee, Under, Beema, Goreh, and Kokree, and some smaller streams. All these have their sources in the Ghàts, within the limits of the collectorate; they converge to the Beema, which falls into the Kistnah, and thus finally reach the Bay of Bengal. The rivers are only navigable during the monsoon, and then only partially. Boats with sails are not seen upon them.

Ahmednuggur Collectorate.—The Ahmednuggur Collectorate adjoins the Poona Collectorate on the east and north. Part of its frontier is along the Ghàts; the rest is bounded by the Chandore range of hills on the north, and by the Nizam's territories on the east and S.E.

Ahmednuggur has an area of 9910 square miles; it contains 666,376 inhabitants, dispersed in 2465 towns and villages, averaging 263·47 inhabitants to a village, (exclusively of the population of Ahmednuggur); 67·24 inhabitants to a square mile; 136,273 houses and 4·89 inhabitants to a house*.

Ahmednuggur is divided into 14 talooks, 36 pergunnahs, and 51 turruffs. Talook Ahmednuggur contains 157 towns and villages, Kurdeh 172, Sungumnair 226, Akoleh 194, Newassa 359, Nasseek 280, Sinnur 107, Chandwur 153, Patodeh 255, Wun Dindooree 175, Barsee 124, Kurmulleh 82, Jamkheir 90, and Kortee 115. The total of these is 2488, instead of 2465; the difference originates in 23 depopulated villages being included. Of the above, 43 towns and 1858½ villages belong to the British; in 27 towns and 554¼ villages the British government has a quit rent, these villages being called Doomaleh,† alienated. Only one village in free gift

* This return is for 16 pergunnahs only.

† The proper meaning of Doomaleh is "two properties," the chief part of the revenue being alienated, but the government having a quit rent.

was returned to me, and one town and three villages in military or feudal tenure; but the villages in free gift (Eenam) are included in the Doomaleh villages.

The chief town is Ahmednuggur, with a population of 17,838 souls in 1822: men 5953, boys 3350, total males 9303; women 5976, girls 2559, total 8535. The other chief towns are Kurdeh, Nasseek, Chandore, Sungumnair, Parnair, &c.; but their population I cannot state, as the total amount of the population of pergunnahs only was sent to me by the collector*. The most populous pergunnah would appear to be Nasseek, containing 71,581 inhabitants. The least populous pergunnah was Soagaon, containing only 9400 inhabitants.

Rivers.—The rivers running through the collectorate are formed by numerous streams originating in the Ghàts and Chandore range,—such as the Peera, the Mool, the Doornah, and the Gooee, which converge to that noble stream the Godavery, which also has its rise in this collectorate, near Trimbuck, and flows to the eastward to the Bay of Bengal. The Seena is the only river of consequence which does not originate in the Ghàts. It has its course at the edge of the plateau on which the city of Ahmednuggur stands, about ten miles north of the city, and flows in a S.S.E. direction into the Beema.

There are several remarkable hill forts in the western part of the collectorate, such as Trimbuck, &c. Ahmednuggur was once the capital of the Ahmed Shahee dynasty of kings.

Khandesh or Candeish Collectorate.—The area of the province or collectorate of Candeish, deduced from a map in the Deputy Surveyor General's Office, including tracts belonging to foreign states and to Jagheerdars, is 12,527 square miles. It is bounded on the north by the Sautpoora mountains; on the east by the province of Berar, belonging to the Nizam; on the south by the Indyadree range of mountains, which separate it from Ahmednuggur; and, on the west, by Dang and Raj Peeplee, which bring it into contact with Goojrat. It is literally a Khind or Khund, a great *gap* between ranges of mountains, whence its name of Khandesh or Candeish. Some of the northern and western parts are little better than a jungle, and the whole province is miserably depopulated. The populated part of the collectorate belonging to the British, derived from the returns of the lands of 1982 populated villages,

* The population returns forwarded by me not having been filled up, in consequence of a census of the population having been made by the collector himself within three years preceding.

give an area of 6760 square miles, with a population of nearly 55 inhabitants to the square mile; but supposing 1684 alienated and deserted villages to have a proportionate quantity of lands, the area will be 12,504 square miles, with $38\frac{1}{3}$ inhabitants only to the square mile, and this I believe to be very near to the truth. It is curious that the area derived from the village lands should approximate so closely to the area determined trigonometrically.

The collectorate is divided into sixty-six pergunnahs, some of which do not contain more than one village each, whilst the largest, Nandoorbar, has 259 towns and villages, Nowapoor 236, Sooltanpoor 232, Rawere 160, Jamnair 144, Amulnair 140, and Bhamere 150, including deserted villages. The total number of towns and villages is 3666; but of this number 330 are *pyegusta*, which means that the villages are deserted, but that part of the lands are cultivated; 999 are entirely deserted; but great confusion and uncertainty prevails in the details, for of this number there are 51 whose limits are unknown, 12 whose sites are *unknown* but names known, and 135 whose *names* and sites are unknown but a record remains of their number. There are 237 populated Jagheer, or alienated villages; and many amongst the Pyegusta, and deserted also, belong to Jagheerdars, so that it does not appear that more than 2032 populated villages belong to the British*; of this number 1968 sent in population returns. The most populous town in Khandesh was Nandoorbar, and it had only 6429 inhabitants; and only one other town (Chopra) had a population of 6000. The towns and villages average only 178 inhabitants, and each house averages 3·96 inmates. The total of the inhabitants is 478,457.

From the village lands in Khandesh being kept universally in Beegahs, the amount of land under cultivation is readily determined. It would appear that 15,958 acres were watered by perennial streamlets. Lands so watered are called *Paht-stul,* and are the most valuable of all, as the supply of water is mostly permanent, and the chief labour required is to open the channels and let it flow over the lands; 46,064 acres were watered from wells, and lands so watered are called *Moht-stul*;† 600,556 acres were under field cultivation, and are not

* In the Collector's revenue return for 1827-8 the number of villages is stated to be $2697\frac{1}{2}$, so that $335\frac{1}{2}$ of the deserted villages had become inhabited, independently of 330 uninhabited villages whose lands were included in the return.

† Paht means a water-channel, and Moht means a well-bucket; implying in the first instance that lands are watered from streamlets, and in the second instance from wells.

watered,—these lands are called *Zerhaeet*. The per centage of cultivated and waste lands in this collectorate is as follows:—

Watered by perennial streams Watered from wells . . . . . Field cultivation	15·32 per cent.
Waste land	84·68 do.
	100 ...

Rivers.—The River Tapty runs through the whole length of the collectorate, and, unlike the rivers of the other collectorates, disembogues into the Gulf of Cambay, below Surat; the water-shed of the country being in fact from the east to the west, instead of from the west to the east; there are some exceptions in rivers which rise in the Western Ghàts, or the Chandore range, and run to the east for some distance, then sweep round in a segment of a circle and join the Tapty; such are the Guirna, Roharee, the Moosum, &c. Timber is floated down the Tapty in the monsoon.

Boodh Cave Temples.—Near to the Adjunta Pass, through the Chandore range, from Ahmednuggur into Khandesh, are a multitude of those astonishing remains of Boodhist art, consisting of excavations in the mural faces of the trap rocks, the interior walls of which excavations are covered with bas-reliefs; indeed, with fresco paintings also, illustrative of the arts and social relations of life, like the paintings on the tombs of the Egyptian kings.

Dharwar Collectorate.—Agreeably to information obtained from the Revenue Survey Department, that part of the southern Mahratta country, bounded on the north by the Kolapoor territory and the Kristna river, on the east by the Nizam's dominions, on the south by Mysore and the Toomboodra river, and on the west by Soonda and the Syhadree Ghàts, comprises an area of 11,747 square miles, namely,

	Square Miles.
British possessions	8378·439
Do. Manowlee Talook, from the Kolapoor territory	390·474
Sawanoor Jagheer	74·750
Sawuntwaree territory	188·934
Nizam's territory	47·930
Gudjundurghur jagheer	69·344
Putwurdun and other jagheers	2597·167
Total	11747·038

The Talooks of *Cheekooree*, 354 square miles, and *Munowlee*, 390 square miles, have been added to Dharwar, so that the area of the collectorate now amounts to 9122·913 square miles; but 39 per cent. of this consists of wood and jungle, and uncultivated lands, and 61 per cent. appears upon the returns as cultivated.

Dharwar is divided into 22 Talooks and 137 *Turruffs*, *Mahls*, *Summuts*, or *Khiryats*, independently of the subdivisions of the Talooks of Cheekooree and Munowlee. The Talook of Dharwar has 136 towns and villages, Meesreekoht 133, Purusghur 59, Nowlgoond 43, Hoongoond 170, Dumbul 96, Bunkapoor 115, Nuwee Hooblee 97, Ranee Beednoor 139, Kettoor 81, Sumpgaon 70, Beereeh 135, Rhone 77, Bagulkoht 141, Hangull 173, Goottull 123, Badamee 148, Padshapoor 202, Kohr 182, Talooks of Cheekooree, and Munowlee 225. To the above are to be added 189 villages, 47 of which sent in population returns, although their names were not in the government lists; 108 were not included because they were Jagheer or Eenam villages; and 34 were depopulated and overlooked. The total number of villages in the collectorate amounted to 2734; of this number 2491 were populated, and 243 were deserted. Of the above, 1899 British villages sent in returns, 225 did not send returns; 155 were deserted, but their lands were under cultivation by neighbouring villagers; 230 alienated villages sent in returns, 137 alienated villages did not send in returns; and 88 deserted villages had not their lands under cultivation. With the aid of some trifling estimates the total amount of population appeared to be 838,757, averaging 91·94 inhabitants to the square mile, 336·71 to a village, and 4·48 to a house. Of the 119 British towns, there are only three whose population exceeds 10,000 souls, viz. Dharwar 11,802; Belgaon 11,037; and Mujeedpoor 15,387. One town has above 8000 inhabitants, (Bagulkoht); two with 6000; one 5000; thirty-six with from 2000 to 4000; and seventy-seven with from 1000 to 2000 souls. All the village lands being kept in definite measurements, it appeared that the cultivated land of the whole collectorate was 61·11 per cent., and waste only 38·89 per cent.

Rivers.—All the chief rivers of Dharwar flow to the eastward; they have their source in the Ghàts, and join the Kistnah. The principal are the Gutpurba, the Malpurba, and the Wurdah: the falls of the Gutpurba, near to Gokauk, are said to be strikingly fine.

Hill Forts.—Dharwar, like the other collectorates, has to boast of its hill forts.

Viewing Dharwar, whether with respect to its numerous towns and well-peopled villages, the comparative density of its population, the size of its farms, the quantity of land in cultivation, the amount of its revenues, the lightness with which they press supposing they were raised as a poll tax, the indications of manufacturing industry (so languishing elsewhere) in the number of its weavers, and its superior means of school instruction, it is unquestionably the finest of the British possessions in Dukhun.

Population.

The great feature in the population of Dukhun is the excess of males over females in a greater proportion than exists in Europe. By the last census in England there were 100 males to 93 females. In the British possessions in Dukhun, in a population from which returns have been received of 2,302,902 souls, there are 100 males to 87·36 females, and this difference obtains, with very little variation, throughout the different casts. It is subject to modification, however, by a very singular fact, exhibited in the excess of grown up women over men wherever the returns distinguish the adults from children; but the excess of male children over female leaves the ultimate preponderance in favour of the males. From Sir Stamford Raffles'. *History of Java*, the same relative proportion of the sexes would appear to exist in that island. He states that the proportion of males and females born in Bantam, and over the whole of Java, is nearly the same as in Europe, and as is found generally to exist wherever accurate statements can be obtained. From the information he collected in a very careful survey of one province, the preponderance seemed to be on the side of male children to an extraordinary degree; the male children being about 42,000, and the female 35,500, i. e. 100 males to 84·52 females. He says also there were formerly great drains on the male population, and which, in advanced stages of life, might turn the balance on the other side; indeed, in some of his returns this is shown to be the case.

In Dukhun, wherever the means have been afforded to me of ascertaining, I have found the preponderance of male over female children to be marked, not only in births, but as long as they continue to be classed as children; although a great mortality, at a subsequent period, makes the grown up females outnumber the grown up males.

Males and females.—In the Poona Collectorate in 1826 the births of males in 32 turruffs were 100 to 94·27 females,

or very nearly 20 males to 19 females. The result of eighteen years' very careful observations for all France, from 1817 to 1834 inclusive, gives 17 males for 16 females; and as this is derived from more than seventeen and a half millions of births, it is worthy of every confidence. Taking each year of the above period, the extreme variation was from 15 males to 14 females, as far as 19 males to 18 females. My deduction varies so little, that we may fairly say the same law equally obtains, whether in a tropical or an extra-tropical climate. Amongst illegitimate births in France it would appear that the number of females approximates more nearly to males than in the legitimate births; the numbers, according to the French tables, being 24 males to 23 females: reducing all these to a common denomination, we have in the

Poona Collectorate . .	94·27	per cent.	of female births.	
In France, the average of 18 years, legitimate	94·11	do.	do.	
In France, legitimate for 1 year, ...	93·33	do.	do.	extremes.
In France, legitimate for 1 year	94·73	do.	do.	
In France *illegitimate*, average of 18 years,	95·83	do.	do.	

It would thus appear that amongst illegitimate children there are nearly two more females born to every hundred males than amongst legitimate births.

In the abstract of the census of the population of the Ahmednuggur Collectorate, taken in 1822, the boys were to the girls as 100 to 62·16; a singular disproportion, there being in the whole collectorate 96,447 boys, and only 59,956 girls; but the men were to the women only as 100 to 102·18, the number of men being 146,750, and the women 149,945. In the city of Poona, in 1822, the boys were to the girls as 100 to 73·26, a greater disproportion than Sir Stamford Raffles found in Java; at the same time the adult men were to the women as 100 to 103·40. In the classes only of the Brahman priests, mendicants, and traders, were the men found to exceed the women. In the city of Ahmednuggur, in 1826, there were 100 boys to 67·62 girls, but 100 men only to 106·06 women; but the ultimate relation of males to females was as 100 males to 92·46 females.

The following table shows the proportion of males to females in the different collectorates, and their principal cities and towns:

Collectorates.	Males to Females.	Cities and Towns.	Males to Females.
Poona Collectorate ...	100 to 88	Poona	100 to 94
Ahmednuggur do. ...	100 to 86	Ahmednuggur	100 to 92
Khandesh do.	100 to 85	Joonur...	100 to 89
Dharwar do.	100 to 89	Dharwar	100 to 98
		Belgaon	100 to 91
		Bagulkoht	100 to 101·25
		Gunness Part	100 to 101·14

Births, Deaths, and Marriages.—Returns of births, deaths, and marriages, in an available form, were received only from 32 turruffs of the Poona Collectorate, comprising 1109 towns and villages, but not including the city of Poona, containing 81,315 inhabitants; my information, therefore, on these subjects must necessarily be circumscribed, but the little there is is valuable from its novelty. Some returns came to hand from the Collectorate of Dharwar, but they were merely additions of the totals of irregular numbers of villages, (from 2 to 12,) and I hesitated to trust to results which I could not test by the original returns. Respecting births, deaths, and marriages in the Ahmednuggur and Khandesh Collectorates, I am totally without information, excepting a solitary return of deaths in the city of Ahmednuggur in 1828, which is worthy of every confidence, as it was compiled by my friend Dr. Walker, late Civil Surgeon at Ahmednuggur.

Births.—In the Poona Collectorate the average births, in a population of 250,300, amounted only to one in 50·52 persons, or not quite two per cent.; the Brahmans having the smallest proportion, (1 in 57·29), and the Moosulmans the greatest proportion, (1 in 40·80); the range of births in the different turruffs was from 1 in 15·70 to 1 in 153·60 persons; and, on the whole, the hilly tracts had a greater number than the plains.

Deaths.—The deaths were 1 in 37·34 persons in the 32 turruffs, or 2·67 per cent., indicating a somewhat alarming diminution in the population;* the range varied from 1 in 17·21 to 1 in 70 persons, the fewest deaths being in the hilly tracts. It must be considered, however, that the spasmodic cholera

* The deaths in the kingdom of Naples for 1836—37 was 1 in 37 and a fraction.

was raging in the country in that year, and that the deaths from that unaccountable and dreadful malady in two turruffs amounted to nearly 5 per cent., and in one turruff to 6 per cent. of the whole population. It is to be presumed, therefore, in the absence of cholera, the births would exceed the deaths, as was in fact the case in some of the Mawuls, or hilly tracts, where it was known the cholera did not penetrate. In deaths the Moosulmans were the greatest average sufferers, (1 in 20·15) and the low casts were the least sufferers, (1 in 42·94).

As Dr. Walker found that the cholera in the city of Ahmednuggur increased the usual deaths 0·66 per cent., the loss being 2·48, while the cholera raged, and only 1·82 per cent. when the scourge ceased, it is but fair to infer that such would have been the case in the country at large; and this element, applied to the mortality in the Poonah Collectorate, would reduce the annual loss to 2·01 per cent., or one death in 50 persons, which would indicate a greater degree of healthiness than all France, all Belgium, or the town of Glasgow, the loss in all these places being 1 in 39 and a fraction.

Marriages.—The average number of marriages in the Poona Collectorate is proportionably more than in England and France, being 1 in 125·87 souls; the proportion in England being 1 in 128, and in France 1 in 130·4 inhabitants. The range in the different turruffs is from 1 in 40·11 to 1 in 493·77; but in 14 turruffs the average is considerably under that for England. The Shoodruhs (Mahrattas proper) and Moosulmans are almost identical, in their proportional number of marriages, namely, 1 in 116·21 and 1 in 116·86, and they have the greatest number of marriages; the low casts have the fewest marriages. The births in 1826 being only 4954 and the marriages 1998, the average of children to a marriage was 2·48 or not quite $2\frac{1}{2}$. In France the average is 3·72 children to a marriage; in England and Wales 3·55. In Java the births were 1 in 39, deaths 1 in 40 persons.

The constituents of the population in the different collectorates were

	Constituents of the Population.				
	Brahmans.	Rajpoots.	Shoodruhs, &c. Mahratta Cultivators, &c.	Atee Shoodruhs, or low casts.	Moosulmans.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Poona	11·58	0·41	73·85	9·78	4·38
Ahmednuggur	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
Khandesh	5·40	3·47	69·58	14·72	6·38
Dharwar	4·48	0·60	74·53	11·895	8·495

In the above analysis the chief features are the permanent and nearly equal proportions of the Shoodruhs or Mahratta cultivators and other genuine Mahrattas, which obtain in the different collectorates; the fact being, that three-fourths of the population are of that most useful class the Shoodruhs; and it will be seen by the notice on agriculture, how large a proportion of them are engaged in tillage. In the Poona Collectorate, as might be expected from its having been the chief seat of a Brahman government, there is a considerable number of Brahmans; every ninth person, in fact, being a Brahman. In the other collectorates scarcely one in twenty persons is a Brahman. Genuine Rajpoots are little known in Dukhun, and I should doubt whether or not the $3\frac{1}{2}$ per cent. of Rajpoots, in the returns from Khandesh, should be added to the Mahratta population; who, by the bye, have some pretensions to being descended from the Rajpoots. The proportion of low casts,* men who are only engaged in vile or discreditable offices by the natives, although otherwise employed by the British, does not differ very much in the different collectorates; the increase in the Khandesh collectorate is attributable to large tracts of the country being inhabited by Bheels, who are a low cast; in fact, less than every seventh person is a low cast; in Poona about every tenth, and in Dharwar about every eighth. The Moosulmans are few in number in the Poona and Ahmednuggur Collectorates, not being one-twentieth of the population in the first, nor one-fifteenth in the second; but, in the Dharwar Collectorate they displace the Brahmans, and amount to nearly one-eleventh. Although the Moosulman power has been paramount nearly throughout all India for centuries, it is believed they have never constituted one-fifteenth of the whole population. In the abstract of the population returns from the Ahmednuggur Collectorate, the casts are not distinguished; but, in a return of 1828, from the city of Ahmednuggur, the Hindoo inhabitants are distinguished from the Moosulman; and it is found that there is the very unusual proportion of one Moosulman to 3·45 Hindoos, or 29 per cent. of the whole population. This is to

* The low casts comprise all that part of the Hindoo population which cannot claim to be Shoodruhs, such as Mahrs, Dhers, Maangs, shoemakers, skinners; Ramoosees, Beruds, and Bheels. The Mahrs and Dhers are the scavengers, the Maangs, executioners; shoemakers and skinners speak for themselves; the Ramoosees and Beruds are *born* thieves, or are thieves by cast, and they are usually employed for the protection of villages, on the principle of setting a thief to catch a thief. The Bheels are supposed to be the aborigines of the countries where they are found.

be referred to the fact of Ahmednuggur having once been the capital of the Ahmed Shahee dynasty of Moosulman kings; with these exceptions, although I have not detailed returns to guide me, I believe that the constituents of the population of the Ahmednuggur Collectorate do not differ in their proportions from those of the Poona Collectorate. In the census of 1822, the families in the fifteen pergunnahs in the Ahmednuggur Collectorate, with a population of 409,279 souls, were enumerated, and it appeared that there were 4·53 persons to a family. With respect to the styles of building in the Ahmednuggur Collectorate, it will be fully illustrated by the facts, that the *tiled* houses amount only to 10·84 per cent. of the whole; the thatched houses to 32·27 per cent.; and the mud flat-terraced houses to 56·89 per cent.

Bearing in mind the clouds of horse that covered the Dukhun in the war of 1817, it is sufficiently remarkable that in 1822, in the whole Collectorate of Ahmednuggur there were only 405 full-grown horses, 1298 full-grown mares; the total, including colts and fillies, being only 2500; the ponies amounted to 12,632, of all kinds.

Proportions engaged in agriculture.—In 1828, in this collectorate, 1878 British villages contained 41,948 cultivators or farmers, and a population of 512,818 souls, and allowing five persons to a cultivator's family, 40·89 per cent. of the people were engaged in agriculture. In Poona there were 52,668 farmers, being a per centage of 55·50, with five persons to a family. In Dharwar 60,701 cultivators, being a per centage of 41·76*, and in Khandesh 44·608 cultivators, being a per centage of 53·16 occupied in agriculture. It is to be understood these proportions have reference to the population of British villages only, and not to the whole population of each collectorate. Moreover, as these proportions are derived from the registered farmers only, and as they are in the habit of subletting their lands, I have no hesitation in expressing my opinion that exact returns would prove that three-fourths of the population are directly engaged in agriculture. In the Poona Collectorate, families were not enumerated, excepting in the return from the city of Poona, and here families average 4·82 persons; each house in Poona averaged 6½ persons; but, for the whole collectorate 4·79 persons to a house; so that it is probable the returns of the number of houses would give the number of families. In Khandesh the proportion of in-

* Including some returns of alienated villages, an estimate makes it 48 per cent.

habitants to a house falls short of the other collectorates, being only 3·96 persons. In Dharwar the number is 4·48 to a house, for the whole collectorate; but the towns exhibit other figures; namely, Belgaon 5·24, Chabee 5·78, and Gunness Pait 5·77 inhabitants to a house; England and Wales has 5·60. The average inhabitants to the square mile, in the different collectorates, has been noticed under the head of civil divisions; and the fewness will disappoint European expectations; but there is plainly a great mistake in the common estimation of the denseness of the Indian population. Bengal proper is said to have 203 inhabitants to a square mile, and Orissa, in the cultivated parts, agreeably to Mr. Stirling, the commissioner, has 135; but, for the whole area of Orissa, the average is only 14½ inhabitants to the square mile; England has 192.

Southern Jagheerdars.—The Southern Jagheerdars have 917 villages, with an *estimated* population of 263,236 souls.

Rajah of Sattarah's territories.—The Rajah of Sattarah, in his territories, has 1703 towns and villages, with an estimated population of 488,846 inhabitants.

With the data in my possession I am enabled to give an estimate of the population of the late Peshwa's territories in Dukhun; it affords a closer approximation to the truth than has hitherto been obtained.

Collectorate.	Towns and Villages.	Explanations.	Number of inhabitants.	Total inhabitants in each Collectorate.
Ahmednuggur	1655½	The census of 1822, in the Ahmednuggur Collectorate, in 1655½ towns and villages, exclusive of the city of Ahmednuggur, each village averaging 263·47 inhabitants, gave	453,098	
	223	223 British villages of Talooks, Kurmulleh, and Korteh, from which population returns were not received, averaging 263·47 souls, give	58,753	
	586½	586½ alienated towns and villages, from which returns were not received, averaging 267·47 souls, will give	154,525	666,376
	23	Depopulated villages		
	2488	Total villages in the Ahmednuggur Collectorate.		

Collectorate.	Towns and Villages.	Explanations.	Number of inhabitants.	Total inhabitants in each Collectorate.
Poona Collectorate.	895½	In the collector's revenue statement for 1828 there appeared 1469½ British villages; viz. 895½ towns and villages inclusive of the city of Poona, which sent in population returns in 1826, the villages averaging 226·10 inhabitants, exclusive of the population of the city, give	283,567	
	212½	212½ alienated villages sent in population returns	48,048	
	56 4	56 alienated towns and villages, and 4 British villages, did not send in returns, averaging a population of 226·10 souls each	13,566	
	574	574 British villages of the Sholapoor sub-collectorates did not send in returns, averaging by estimate 226·10 souls each	164,294	
		Had the average number of inhabitants to a village in the Ahmednuggur collectorate been used as an element, the result would have been 151,145		
	155	155 alienated towns and villages of the Sholapoor sub-collectorate at 226·10 souls each ...	40,838	550,313
	29	Depopulated villages.		
	1926	Total towns and villages in the Poona Collectorate.		
Khandesh Collectorate.	1968	In the collector's revenue statement for 1828, there were 2697½ villages; of this number, 1968 British towns and villages sent in population returns in 1826, averaging 187·39 inhabitants to a village, equal to	368,781	
	64	64 villages, refused returns, at 127 souls each	8128	
	330	330 villages are cultivated, but not inhabited, making a total of 2362 villages. To make up the		
	335½	number in the collector's revenue statement therefore, 335½ villages must be added as having become populated since the population returns were sent in, at 127 souls each	42,608	
	14	14 Jagheer villages sent in returns	2623	
	300½	Jagheer, or alienated villages, did not send in returns, at an average of 187·39 souls each	56,317	478,457
	654	Depopulated villages, lands not cultivated.		
	3666	Total towns and villages in the Khandesh Collectorate.		

Collectorate.	Towns and Villages.	Explanations.	Number of inhabitants.	Total inhabitants in each Collectorate.
Dharwar Collectorate.		In the collector's revenue statement for 1828, there appeared 2279 towns and villages; of this		
	1899	number, 1899 British towns and villages sent in population returns, averaging 348 inhabitants to each village	660,852	
	225	225 British villages in the talooks of Cheekoree and Munowlee did not send in returns; estimating their population from the revenue they yield, falling as a poll-tax as in other parts of Dharwar, there are	65,805	
	155	British depopulated villages, lands under cultivation.		
	230	Alienated villages sent in population returns	79,727	
	137	Alienated villages did not send in population returns, at the lowest average of population, 236·30 each	32,373	838,757
	88	Deserted villages, lands not under cultivation.		
	2734			
Southern Jagheerdars' lands.	917	The area of the Southern Jagheerdars' territories is 2978·125 square miles at 88·39 inhabitants to the square mile, the lowest average of the Dharwar Collectorate gives by estimate	263,236	263,236
Rajah of Sattarah's territories.	1703	1703 towns and villages under the Sattarah government, with an estimated population of 287·05 inhabitants to a village, which is the mean between Dharwar and Ahmednuggur, will give	488,846	488,846
	12,155	Populated villages.		
	1,279	Depopulated villages.		
	13,434	Total.		3,285,985

ABSTRACT OF THE ABOVE.

Collectorate or Territory.	Area, squaremiles.	Number of Towns and Villages.	Population.	Average to the square mile.	Average to a village for the whole Collectorate.	Average to a house.
Poona	8281	1926	550,313	66·45	* 247·36	4·79
Ahmednuggur	9910	2488	666,376	67·24	† 263·47	4·89
Khandesh ...	12,527	3666	478,457	38·19	178·39	3·96
Dharwar	9122	2734	838,757	91·94	336·7	4·48
Southern Jagheerdars......	2978	917	263,236	88·39	287·05	Not known.
Rajah of Sattarah's territories	6169	1703	488,846	79·25	287·05	Not known.
Total	48,987	‡ 13,434	3,285,985	67·07	270·34	

Average number of inhabitants to a village for all the collectorates, 270·34.

The above population does not include the army, camp followers, Bheels, or the wandering tribes.

It would appear there are 1279 uninhabited villages in the four collectorates of Dukhun, principally in Khandesh; making a total of 10,814 towns and villages in the British possessions, and of 13,434 in the late Peshwah's territories in Dukhun; exclusive of those belonging to the Kolapoor state.

Total alienated villages in the four collectorates, 1695½. Total British populated villages, 7839½; total deserted, 1279. Total villages in the *four collectorates*, 10,814.

Education.

Education, as a regular system, is certainly unknown amongst the people in Dukhun. The few schools existing are wholly disproportioned in number to the population; and even were they more numerous, the present general poverty of the Koonbees,§ and the imperious calls upon them for the services of their children in agriculture, and in attending their cattle,

* Exclusive of the population of the city of Poona.

† Exclusive of the population of the city of Ahmednuggur.

‡ Of this number, 1279 are depopulated, and the depopulated villages of the Southern Jagheerdars and Rajah of Sattarah's territories are not known to me.

§ Mahratta cultivators.

would disable them from letting their children profit by instruction, even though gratuitous. In a stage of civilization which is by no means contemptible, the general illiterateness of the cultivators is remarkable. It might have been supposed that the pressure of the inconveniencies and the risk of loss attending the solving their constantly recurring arithmetical computations, whether in settling their assessments with government, in ascertaining the amount of their produce, or in computing its saleable rate to ensure a profit, or in their money transactions with each other, would have stimulated some families of the past or present generations to have pursued steadily a course of instruction for their children, which, by its example and the visible beneficial results attending it, would have originated a thirst of knowledge, and advanced the march of intellectual improvement. The Shoodra, however, is led to believe by the wily Brahmans that letters and science are not within his province, and the farmer is content to go on mastering his arithmetical difficulties with the assistance of his fingers, and relying upon the village clerk for the keeping his accounts with the government, and on his ability, judgement, and secrecy in the management of his private correspondence, which, it may be supposed, will not be very important or voluminous. Were it ascertained, I believe not one cultivator in a hundred would be found able to write, or count up to 100 but by fives; and my daily unreserved intercourse for hours with numbers of this class of persons has given me facilities for forming this opinion. And yet the Koonbees are far from wanting intelligence; they are not slow in observing; they are quick in communicating, and the rationale of an agricultural process is frequently explained with a simplicity and effect which we might not always meet with in the educated English farmer. There would not be any difficulty in teaching the Koonbees, provided the instruction were gratuitous, and that the farmer could spare his children; and several important effects might attend this instruction: the mind of the cultivator would be invigorated with new ideas; enlarged views of action would break in upon him; a spirit of improvement, enterprise, and innovation might spring up, in place of the apathetic routine that at present prevails in rural œconomy, and in the social relations of life; and an amelioration, both physical and moral, would take place in his condition. But at present the little education that exists is confined to the Brahmans and to the shopkeepers, Shaitees*, and Mahajuns.†

* Heads of trades. † Bankers.

The Koolkurnees*, or accountants and village-clerks, are always Brahmans; many of them are shrewd and very quick, and possessed of infinite ingenuity in avoiding the detection of a fraud or mistake in their papers; many of this class, however, I found too stupid to keep an individual's account, much less the complicated details of a village assessment. The shopkeepers being generally people from Goojrat, keep their accounts in the Goojratee language. The character in universal use for business is the Mohr in the districts. The following will show the number of schools, as far as the returns received from the collectors will permit,—not any account of schools was received from the collector of Ahmednuggur. In the Collectorate of Dharwar there is one school to 2452 inhabitants; in Khandesh there is only one school to 4369 souls; and, in the Poona Collectorate, deducting the population of the city of Poona, there is one school to 3337 souls. It is fair to infer therefore, that as Dharwar supports proportionably so many more schools than the other collectorates, that information is more generally spread amongst the people, and that they are better able to manage their affairs than others less instructed; and the breadth of cultivation, and general manufacturing and commercial industry of the people, would seem to justify the inference.

Irrigation.

Preliminary to speaking of agriculture, it is necessary to state that lands are watered artificially in two ways. First, by conducting streamlets from running rivers or brooks. Lands so watered are called Paatsthul, from Paat, a channel, and Sthul, a field.† These streamlets do not always last through the hot season; and though this species of irrigation, while available, is infinitely less onerous and less expensive to the cultivator, affording also a more plentiful supply of water than the well watering and great returns; yet it is not so certain, and, on the whole, is less permanently efficient than well watering. The second method is by well watering. Lands so watered are called Moht Sthul, from Moht, the water-bucket, and Sthul, a field. There is a good deal of trouble attending this method, and it requires the continual expense of the support of two or four bullocks, the wear and tear of materials, and the keep of one man, who, however, can readily manage two buckets, and two pairs of bullocks: at the same time it requires also a boy in the garden or field to open and shut the different channels.

* Village clerks and accountants.

† Literally "firm land."

This is the most common method of irrigation in the districts reported on. Usually only two bullocks are attached to each bucket; in some instances, however, where the wells are deep, four bullocks are attached to each bucket. The cattle pull down an inclined plane and discharge the water, and readily walk backwards up the plane to the highest part of it; on the bucket being refilled, they go down the plane again; the driver sings to them and rides down on the rope. The process is suspended for an hour or two during the middle of the day. The accompanying drawing illustrates this process, and does not require any explanation. A very considerable quantity of water is brought up by this method. The buckets in use vary little in size, and the wells, probably, range from 25 to 45 feet deep; some experiments of mine, therefore, to ascertain the quantity of water brought up from a well 35 feet deep in a certain time, may be considered as an average of the efficiency of this method of irrigation. I found a moht (of six paahls) average a delivery of 198 wine bottles of water each time. The bottle contained 28 ounces of water, apothecaries' measure, consequently the bucket contained 5544 ounces wine measure, 231 quarts, or 57 gallons 3 quarts. There is a singular uniformity of time between the delivery of two buckets, seldom exceeding seventy seconds; a man and a pair of bullocks, therefore, in an hour deliver 2931 gallons of water; and, labouring seven hours a day, give 20,517 gallons wine measure; and the same man with two pairs of bullocks delivers 41,034 gallons of water; a quantity infinitely exceeding what Europeans usually believe to be drawn up by the simple means employed. At eight pounds troy to the gallon, the weight of water drawn up by one pair of bullocks in one day will be 164,136lbs. troy; and by two pairs of bullocks, 328,272lbs. troy. This account appears very considerable, but my experiments have been repeated with care; and, on the whole, the delivery of water may be rather underrated than overrated.

Near the village of Piroorgoot, I observed a simple method of watering a field. The bed of a nullah, or rivulet, with very low banks, had been dammed up; three pieces of wood, like a gin, were put over the water; a scoop was suspended by a rope to the apex of the gin, and a man scooped out the water into his field. The labour was great, and the supply of water small. This apparatus is called Dohl.

It would appear to be of considerable importance to encourage the making of wells, as the only means of increasing the very limited exports of the Dukhun.

Agriculture.

Some general observations will be necessary, as the crops and agricultural process in the Mawuls * differ materially from the crops and agricultural process in the Desh.† The principal crop of the Mawuls is that of the rains, and the most valuable of its produce is rice ‡. The severe labour attending the preparation of the rice ground in the hot weather is great, and in the rains the cultivator has to trample up to his knees in water and mud ploughing the rice field, probably in a deluge of rain, but with his head and back most securely protected by the Eerluh §, however much exposed the rest of his body may be. The transplantation is performed under similar exposure. The other monsoon grains of the Mawuls are the Sawa, Wuree, and Natchnee, and Karlee, or Kalee Teel ‖ which is an oil plant of the only other monsoon product.

The labour attending the cultivation of these grains, in a very unfavourable climate, at the time they are grown, falls very severely on the people, but they are compensated for their labour and suffering by good returns of that valuable produce rice; and the returns of the other grains are great, and the crops seldom fail.

The Koonbees, or farmers of the Mawuls, also have an advantage which those of the Desh are not always assured of, i. e. the certainty of finding a market for one of their products, rice.

Dry Season Crop (*Mawuls.*)—The dry crop of the Mawuls does not call for any mention in this place.

Dry Season Crop (*Desh.*)—With respect to the Desh, the most valuable is the Rubbée, or *spring* crop ¶. The agricultural processes in both crops is certainly defective, less owing to the ignorance of the cultivators, who are well aware of the advantage of a ploughing adapted to the character of the soil, of good manuring, complete weeding, rotations of crops and fallows; than to their necessities, which compel them to rack their land; they cannot generally afford to purchase a sufficiency of

* Hilly districts along the crest of the Ghâts.

† Flat country, eastward of the Mawuls.

‡ Vide No. 118, wet crop, Mawuls.

§ Eerluh, or basket-work hood, covered with leaves and quite impervious to rain.

‖ Wet season crop (Mawuls.)

¶ Consisting of wheats, gram, barley; Shaloo, (*Andropogon Saccharatum*); Dhal, (*Cytisus cajan*), oil-plants, &c.

manure, they have not any stable-yards, and the dearth of fuel compels them to burn much of their cow-dung; and, with a singular fatuity and injurious caution, they sow half a dozen grains and pulses together in the same field, which necessarily impede the growth of each other, exhaust the soil, and give limited returns. The professed object is to assure, in the occasional uncertainty of the monsoons, some kind of return at least for their labours, which might have been wholly unproductive had one grain only been sown. In short they want to have half a dozen strings to their bow instead of one.

Wet Crop (*Desh.*)—The grains so sown ripen in succession, and two of them remain on the ground between nine and ten months; that is to say, from the beginning of June to the end of February. In their management of the plough, the Koonbees do not want dexterity. Their cattle have all names, know their names, and are obedient to them; with four bullocks to a plough, the leaders are guided entirely by the voice, and I have frequently seen quite a youth managing alone very cleverly his plough and four bullocks.

In the Desh, in manuring land, the cart called *Jang* or *Janjeea,* is used; it consists simply of the common cart with a quite flat basket tied on the top of it, made by the Koonbees from the twigs of the Neergoondee, (*Vitex trifolia,*) or of the twigs of the Tooree, (*Cytisus cajan.*) The manure generally consists of the sweepings of their houses, which, from being usually cow-dunged every day and daily swept, are not trifling, and from the ashes also from their hearths.

Crops are carted to the *Kulleh,* or farm-yard, from the fields by the Garra. This consists of an upper horizontal rude framework supported on a thick axle-tree, and is removeable at pleasure. The wheels are of solid wood, small, placed under the frame-work, are not sufficiently far apart, and consequently subject the cart to upset, which is but too frequent an occurrence. Wooden pegs and thongs keep the whole vehicle together, and there is no more iron about the cart than the tire round the wheels and the hollow cylinders within the naves. This vehicle, considering the circumstances of the Koonbees, is expensive, costing from eighty to one hundred rupees, and it is only the most substantial among them who have carts. Having carted their grain, the Koonbees remove it to the Kulleh, or farm-yard.

Farm-yard.—The grain is stacked round a spot in the open air in a corner of one of their fields. This spot is circular, and has been prepared by beating and cow-dunging; a pole, called *Tewrah,* is fixed in the centre of it. In the reedy grains the

heads are broken off by women, and strewed round the pole* to the depth of 5 or 6 inches. In the ligneous pulses, the extreme twigs, bearing the legumes, are broken off and strewed round the pole; and in the herbaceous leguminous pulses and straw-culm grains, the whole plant is put on the floor: six, or eight, or more bullocks (I saw sixteen at Munchur) are tied side by side, half on one side of the pole and half on the other; they are muzzled and driven round the pole, treading out the grain. This process usually occupies two men, and it is called the *Mullnee*. It is neither inefficient, nor dilatory. It would appear to be of great antiquity, and widely practised; in Deuteronomy, xxv. 4. we read, "Thou shalt not muzzle the ox when he treadeth out the corn."

Winnowing.—We are now brought to the winnowing the grain. This is done in the Kulleh; and when there are sufficient members in the family of the farmer after the first treading, the process is carried on simultaneously with the Mullnee. The process is very simple, but certainly not very efficient, as it is dependent on the wind blowing. In case the wind blows very hard, the grain is blown away; and in case the wind is not strong enough, the husks fall with the grain. A man stands upon a tall three-legged form, called the *Wawhree*, and pours the grain taken up from the treading ground, out of the winnowing basket (*oopunwutee*). The full grain falls perpendicularly and is pretty free from husks, but the lighter grain falls obliquely, and is partially mixed with the husks. A man sits at the base of the stool or form with a broom (*aatuee*) in his hand to assist in removing the chaff from the edges of the mass of fallen grain. After all is done, however, it is requisite to pass a good proportion of the grain through the sieve, (*Chalun*). After the grain is winnowed it is carried home and laid in store.

Preserving Grain.—There are various ways of preserving the grain. Where the soil is sufficiently dry, chambers are dug in the earth for it; but the most usual plan in the districts is to preserve it in large baskets, called Kuneeng, made of twigs of the Neergoondee, (*Vitex trifolia,*) or of those of the Tooree, (*Cytisus cajan*). These baskets are plastered with cow-dung inside and out, and are perfectly impervious to rain or damp. Where the habitations are sufficiently large, or the baskets few in number, they are lodged in the house, but not unfrequently are placed outside of the house within reach of any pilfering hand. A few stones are put under each

* Tewrah.

basket; the lid, in case it has a lid, is sealed down with cow-dung, and in case it has not a lid, a plaster of cow-dung a couple of inches thick is put over the grain; a little cap, or roof of grass, is put over the basket, and it is left exposed till required, being deemed equally protected from the elements and man. In the Mawuls, in the hot months, the whole of the grain baskets of the village, full of grain, may be seen assembled in front of the village temple, and left to the custody of the village god. The roofs of all the houses are of grass in the Mawuls, and the dread of fires (the people having no chimneys to their houses) induces them to put their monsoon and winter stores in a place of safety, the extreme dryness of the period rendering accidents by fire frequent. It is not an unfrequent practice with the Koonbees of the Mawuls to unroof their houses for the months of April and May.

In addition to the baskets for the preservation of grain, earthen jars, called *Kothee,* made by the people themselves, are met with to hold grain, but they are not common.

Preparing Grain for Food.—The preparation of grain for food is the last process. Husk grains, such as rice, Wuree, (*Panicum miliare*); and Sawa, (*Panicum frumentaceum*); and the Johr, or husked wheat, require to be pounded to remove the husks. This process is entirely within the province of the women: the implements used may be called the pestle and mortar; the mortar is called the ookul, and the pestle, moosul. The mortar in the Mawuls is frequently very rude in form, being a rough stone with a hole scooped in the middle of it to receive the grain. In the Desh, however, the mortar is of wood, of a good form, and sometimes carved. The *moosul,* or pestle, is always of wood, four or five feet long, tipped with iron, and in thickness and weight suitable to the strength of the person to use it. The final process is the grinding the corn; this also is the duty of the women, and two of them are usually employed at the mill. Christ says, "There shall be two women grinding at the mill;* one shall be taken and the other left."

Hand Mill.—The mill is portable, and is called Jatuh: it consists of two flat circular stones, fourteen or eighteen inches in diameter, placed one on the other; the lower one has an upright peg in it, the upper one has a hole in the centre through which the peg of the lower stone passes, and the upper stone is made to perform an horizontal rotatory motion round the peg by means of another upright peg near its margin. The grain is put in at the hole in the centre. This form of mill must be

* Matth. xxiv. 41.

very ancient, for I saw remains of such mills in the ruins of Pompeii, and one nearly perfect in the ruins of the Roman villa of Sir William Hickes's estate near Cheltenham, Gloucestershire.

Raw Sugar Mill.—Under the head of agriculture it will be necessary to speak of the Gool, or raw sugar-mill. Sugar cane is not so much cultivated as it might be, and it is seldom found but at populous villages. I have seldom seen more than two mills at a village; and as the screws and accompaniments are somewhat expensive for the circumstances of a cultivator, the mills are seldom found belonging to him, but he is a renter of them for the term requisite. The mills are in the open air, and consist of two vertical screws which are sunk in a square chamber excavated in the earth; one of them is moved by a double lever so much elevated above the level of the field as to admit of bullocks being attached to the ends of the lever. The cattle go round incessantly in a circle and work the mill. The bits of sugar cane are passed twice between the screws, and the juice runs out into a wooden or copper vessel placed to receive it. The fire-place (Choolangun) and great iron pan (Kurhuee), to boil the juice in, are close at hand; a ladle to stir and skim the juice as it boils, and some circular holes in the ground to receive the juice when sufficiently thick, complete the material and close the process. The work is continued night and day till the cane-field is exhausted. Sugar is not refined in the Dukhun.

Oil Mills.—Although the oil mills belong to a class of persons who are not agriculturists, the Koonbee is quite dependent on them to turn his numerous oil seeds to account; some mention therefore of them is necessary under "agriculture." The body of the mill is generally of stone, and the machinery, even when of the rudest construction, shows a good deal of ingenuity and an acquaintance with some of the mechanic powers. It is entirely the work of the village carpenter.

At Neelsee, a Kohlee village in the wilds on the brink of the Ghàts, the body of the mill is of wood, the lever works in the hollow of an upright cylinder, and by the great weight attached to its upper end constantly presses against the sides of the hollow and forces the oil from the seed which is put into the mill. The whole expense of the machinery of this particular mill was only five rupees *. In the Desh the body of the mill is of stone, the machinery is the same as in this mill. It is worked by a bullock.

Average Size of Farms.—There are not any farms of large

* About ten shillings.

size under the management of a single farmer; the largest I recollect meeting with was about 200 acres, but in general they average very considerably less in size. In the Poona Collectorate the average size was 29 beegahs*, in Ahmednuggur 35 beegahs, in Dharwar $43\frac{6}{100}$ beegahs, and in Khundesh $23\frac{68}{100}$ beegahs. The average rent of a farm in Poona was less than 48 shillings per annum; in Ahmednuggur about 86 shillings; in Dharwar 64 shillings; and in Khandesh, where a good deal of the land cultivated is garden land, 74 shillings per annum. In Poona the average rent per beegah is within a fraction of two shillings; in Ahmednuggur about two shillings and six pence per beegah; in Dharwar not quite eighteen pence; and in Khandesh, where there is proportionably a good deal of garden land, it is somewhat more than three shillings a beegah. The average for the whole of the lands of Dukhun is two shillings and ninepence, one-eighth per *English acre,* or one rupee and fourteen reas per Dukhun beegah.

Proportion of Yoke Cattle to each Farmer.—Generally in the population returns there were great omissions of the draft or yoke cattle of the cultivators; no very satisfactory statement can therefore be given of their agricultural means in this kind of stock. In one Talook, or county, of the Dharwar Collectorate, the yoke cattle were filled in, with the exception of two or three village returns, and the proportion is only 1·38 bullocks to each cultivator; but as the ploughs are 3733 in number in the Talook, at two bullocks to a plough, the proportion should be 2·89 bullocks (nearly 3) to a cultivator: the returns must be defective, for I am satisfied, although a farmer may not have two bullocks to each of his ploughs, and he has generally a heavy plough and a light one, yet he has always two bullocks at least for one of his ploughs.

In the Ahmednuggur Collectorate the yoke cattle are not distinguished from the pack or carriage cattle, but the whole amount is very considerable, being 212,008. In the Poona Collectorate the returns give $2\frac{1}{4}$ yoke bullocks to each farmer, but the farmers near to the city of Poona are much better off, averaging $3\frac{1}{2}$ bullocks each. Only a portion of the returns from Khandesh had the column of draft or yoke cattle filled up; it is impossible, therefore, to give the proportion to each farmer for the whole collectorate; but as far as the returns went, it appeared that each farmer averaged only 1·62 bullocks, not quite $1\frac{3}{4}$.

* The Dukhun beegah is three-fourths of an English acre. The rupee is valued at two shillings.

Milch cattle.—The proportion of milch cattle, on which so much of the comfort of the people depends, whether rural or urban, in the Dharwar Collectorate, is greater than in the other collectorates, being one cow or milch buffalo to 2·45 souls. In Poona it is 1 to 5·24 persons; in Ahmednuggur 1 to 3·04 persons; and in Khandesh 1 cow or buffalo to 2·26 souls.

Ploughs.—As I have before stated, ploughs are of two kinds, the Nangur or heavy plough, and the Hulka Nangur or light plough; the same obtains with respect to drill ploughs, no grain being sown broadcast, the heavy drill plough being called Mogurh, and the light Pabhar. The proportion of ploughs in the Dharwar Collectorate is 1·41 to each cultivator, or nearly three ploughs to two farmers; the number of ploughs in the returns being 99,883, and the number of cultivators 70,488.

Carts.—Were a judgement to be formed of the state of the roads, and of the facility of communication and transit by wheel carriages, from the proportion of carts to the farmers, the estimate would be low indeed.* In the Dharwar Collectorate there is only one cart to thirteen farmers. The carts are universally of two wheels.

Pack cattle.—The unusual number of pack bullocks, which carry loads on their backs, in the Dharwar Collectorate, would seem to indicate that they are the chief means by which agricultural and other produce is transported from place to place. In Khandesh there is the least number of pack cattle, and the greatest proportional number of carts. In Poona a great number of pack cattle, and only one cart to eleven farmers. The proportion in Ahmednuggur I do not know.

Land and other Tenures.

Lands are held under a great variety of tenures in Dukhun, some by virtue of offices which are hereditary, some as hereditary freehold property, some in free gift from the state, some in Jagheer or military or feudal tenure, some on a quit rent, and in many other ways; but a rapid notice of the different tenures, and of the office-bearers holding lands, will best assist to give a clear idea of their quality and number.

In the first place, the proprietary right of the soil was (and is) in the people, and not in the sovereign. The sovereign could assess the land as he pleased, and assign away a part or the whole of the revenue arising from the land-tax or assessment, either in free gift (Eenam), military tenure (Jagheer), or quit rent, or in any other way; but he could not

* It is nevertheless true, that had the farmers carts, they could rarely use them from the want of roads, unless in the dry season.

justly take away a man's land either for his own purposes or to give it to others; although, as a despotic prince, like all other princes of India, he had the undoubted *ability* to do so at his pleasure: yet few instances are known of this oppressive exercise of their power, and there are many instances on record of their purchasing land from their subjects. I have laid before the public translations of official documents, in which the sovereigns have been parties, containing the most irresistible proofs of the people having the uncontrolled right to dispose of their lands as they pleased, by gift, or sale, or devise, or in other ways. These translations are too lengthened to be introduced in this report, but they will be met with in the Journal of the Royal Asiatic Society of Great Britain and Ireland.

All lands in Dukhun were classed within some village boundary or other; and to this day these boundaries are guarded with such jealousy by the inhabitants as to be productive of broils and bloodshed on their slightest invasion. The village lands were divided into family estates, called Thuls, which bore the name of the family, and the estates bear the name to this day, although the family be extinct or Gutkool, as it is called; and half the estates in Dukhun are now Gutkool, but preserve their family names. These estates were hereditary and freehold, burthened only with the sovereign's land-tax, and assessments for village expenses, as a gentleman's estate in England is burthened with land-tax and assessments for highway and poor-rates, &c.; there were not any tithes, but in each village there were lands assigned for religious objects, either to temples or to sacerdotal persons. Every village had a constitution for its internal government; it consisted of the Pateel or chief, assisted by a Chowgulla; the Koolkurnee, or village accountant, kept the village records and details of assessment and revenue; and there were twelve hereditary village officers, the well-known Bara Bullooteh, whose numbers were complete or otherwise as the population of the villages was capable of supporting them. All these officers and the chief land-owners formed a village council, called Pandreh, which managed the external and internal relations of the village, whether with respect to raising the government assessments, managing its police, or in settling civil disputes, excepting in cases where Panchaeits or juries of five persons were specifically appointed to arbitrate by mutual consent of the litigating parties. And it is somewhat remarkable that this isolated and internal government has withstood the shocks of all the changes of dynasties, invasions,

rebellions, and the destructive anarchy which have so frequently disgraced the annals of India.

A certain number of villages constituted a Naikwuree, over which was an officer with the denomination of Naik. Eighty-four villages constituted a Deshmookee, over which was an officer called a Deshmook, or governor,* possibly equivalent to our lord-lieutenant of counties; this officer was assisted by a Desh Chowgulla; and for the branch of accounts there was a Deshpandeh or district accountant and register. The links connecting the Deshmooks with the prince were Sur-Deshmooks, or heads of the Deshmooks; they were few in number. It is said there were also Sur-Deshpandehs. The Sur-Deshmooks, Deshmooks, and their assistants, Naiks, Pateels, and Chowgullahs, indeed all persons in authority, were Mahrattas; the writers and accountants were mostly Brahmans. Such was the state of things under the ancient Hindoo governments. The Moosulmans on their conquest, in the civil divisions of the country, introduced the terms of Soobeh (a province), Pergunnah (county), Tallook (manor, lordship), and Turruff (a division of a county). The Hindoo hereditary officers were deprived of their authority, (excepting those in the village constitution,) but, very liberally, they were not deprived of their tenures; and their places were supplied by Zemindars,† Maamlutdars, Sheristehdars, Havaildars, &c.

I have stated that the family estates were called Thuls, from the Sanscrit *Sthul*, "firm land;" and in case the family became extinct or Gutkool, from the Sanscrit *Gut*, "gone, passed away," and *Kool*, "a race or family," the property did did not pass to the sovereign, but it was at the disposal of the Pateel solely, or the village corporation conjointly, to do as they pleased with it; and I have multiplied proofs in my possession of freeholds having been created in such estates of extinct families, by letters of inheritance, called Meeras Putra, which were granted by the Pateel or village authorities for a sum of money; and such letters became title-deeds, similar to those of an estate in England. The law of succession by primogeniture not obtaining amongst the Hindoos, these estates

* Called also Desaee or Deshaee in some parts.

† Mistakes, very serious in their consequences, have been made with respect to the supposed rights of Zemindars. They were introduced by the Moosulmans, superseding the ancient Hindoo Deshmooks and Desaees, and were government officers for the collection of the revenue, and for the civil government of districts. In Bengal, the British considered them proprietors of the soil, and constituted them as great freeholders; sweeping away the village freeholds.

became necessarily much divided, and the individual holders were called by the Hindoos Thulwaee or Thulkuree; and the light in which the Moosulmans looked upon such proprietors, when they took possession of the country, is sufficiently manifest by the term they applied to them, namely, Meerasdars, or patrimony-holders, from the Arabic word *Meeras*, "patrimony," "heritage," and *Dar*, "a holder;" and this is the term by which such proprietors are distinguished at the present day. The Meerasdars were of two kinds; the descendants of the original proprietor, whose *surnames* and the name of the estate or thul were identical, and those who had obtained a share of the estate by purchase or otherwise, whose surnames were not the same as that of the estate. In no instance, that I am aware of, have the former class documentary proofs of their right; with the latter class documentary proofs are not uncommon.

There is further proof of the Moosulmans having acknowledged hereditary rights in the term they applied to the Deshmooks, Desaees, Deshpandehs, and others, namely, Hukdar. *Huk*, in Arabic, meaning "right," and *Dar* "a holder;" these persons in virtue of their offices having lands in tenure and fees in money and kind in the districts in which these duties lay. The Meerasdars considered that they might be temporarily dispossessed of their freeholds in case of non-payment of the government assessments and dues, but they claimed to resume them whenever they had liquidated their debts; and they did not consider the question of these freeholds compromised by the government doing justice to itself, any more than the existence of freehold property would be questioned in England because the owner might be compelled to yield up his property in payment of arrears of land-tax, poor-rates, &c.

Meerasdars.—Meerasdars set a very high value upon their lands, and they clung to them with that feeling of personal and family pride which are characteristics of freeholders in Europe; even under the most grinding oppressions of their own government and its local officers, it was only when driven to despair that they abandoned them. The Meerasdar had to pay the government land-tax, all fees in kind to the district and village officers in common with the tenant at will or leaseholder; moreover, he had to pay a tax applicable to himself only, called Meerasputtee, a kind of smart-money for the distinction his freehold gave him; this was levied every third year. Such was the Meeras tenure of land. His advantages were, first, the distinction; next, his being a constituent of the Pandreh, or village

corporation, which the mere renter was not; and thirdly, in some parts of the country where such taxation existed, he was exempt from marriage fees, widows' marriage fees, buffalo tax, hearth tax, and he may have paid a diminished per centage, in the rights of district officers levied in kind. Of late years, from the low prices of agricultural produce and the comparatively heavy money assessments, Meeras-land has scarcely had a saleable value. The terms Meerasdar and Wuttundar have usually been considered identical, but in some village papers I observed them classed separately; and, on asking for an explanation, was told that the Wuttundars were hereditary office-bearers, or the relations of hereditary office-bearers with the possible right of succession, whilst the Meerasdars were merely hereditary landholders; a Wuttundar would necessarily be a Meerasdar, but a Meerasdar was not necessarily a Wuttundar.

Oopuree.—From the extinction of numerous Mahratta families who were in possession of estates, a considerable portion of the land in Dukhun is without proprietors, and much of it is rented to Oopurees or annual tenants by the Pateel or village corporation, under native governments; but, under the British government, by the collector or his officers. The term Oopuree means "a stranger," or a renter of land in a village in which he has not corporate rights: of course, Meerasdars can let their lands to each other, but they do not become Oopurees. The Oopuree holds his lands on the Ooktee, or word-of-mouth tenure, which is a verbal agreement for one year.

Kowl Istawa.—The third tenure is that of Kowl Istawa; *Kowl* means a contract, and *Istawa* is applied to lands let under their value. In practice, to induce cultivators to break up land that has long lain waste, a lease is given of three, five, seven, or nine years; the first year a trifling rent is fixed, and it is annually increased, until in the last year of the lease the full rent is paid; this tenure is highly desired, and great abuses exist under it: the permanently assessed cultivator is prompted to quit his village, and abandon even his hereditary lands, and get Kowl Istawa lands in another village; and the moment the favourable lease is up he changes his location, and endeavours to obtain similar terms elsewhere: the practice, therefore, is detrimental to the permanent revenue, detrimental to the sound advancement of agriculture, and detrimental to the cultivator himself in encouraging vagrant habits. The local authorities also are found to be great occupiers of Kowl Istawa lands.

Owand tenure.—Any inhabitants of a village, cultivating lands in a neighbouring village, but not residing in that village, do so on the Owand tenure. The rate and terms are the Ooktee, and with respect to the village such cultivator is, in fact, an Oopuree, but his distinctive appellation is Owand-Kuree.

The above are the tenures on which the government land revenue is raised, which in the four collectorates of Dukhun amounts to 82·372 per cent. of the whole revenue; this per centage, however, includes some trifling rents from government lands, gardens, orchards, grass lands, and sheep grazing, quit rents, fees, Hukdars, and extra cesses.

Tenures involving alienations of lands.—I have now to speak of tenures which involve alienations of lands, from a few beegahs in a village, to whole districts: these are *Jagheer* and *Eenam* in Khandesh; *Surinjam, Eenam,* and *Doomalla* in the Ahmednuggur Collectorate; *Eenam, Surinjam,* and *Eesaphut* in Poona; and in Dharwar, *Jooree Eenam, Surwa Eenam,* and *Jagheer:* at least, such terms appeared in the population returns sent to me, and in the public papers which I have.

Jagheer.—Jagheer, which is a Persian word in its origin, is applied to lands given by government (or the government share of the rents) for personal support, or as a fief for the maintenance of troops for the service of the state: some service is implied in the personal as well as in the military Jagheer. In the Collectorates in Dukhun upwards of 400 populated villages appear to be alienated in Jagheer.

Eenam.—Eenam is a word of Arabic origin, meaning a "gift," "present;" and lands so held should be entirely free from tax to government; but a subsequent explanation of various tenures will show that Eenam has a much wider signification than is generally supposed. This tenure is very extensive in Dukhun; for independently of the grants of whole towns and villages to individuals, of which there are 231 alienated in the Poona Collectorate alone, and the other Collectorates have a proportional share; independently also of grants for temples and religious institutions, almost every village has Eenam land held by the Pateel, Koolkurnee, and Mahrs, and very commonly the Deshmooks and Deshpandehs have also land rent free appertaining to their offices in the villages of their districts. The Bara Bullooteh, or twelve village artizans and officers, have often Eenam lands, but their Eenam is qualified by the imposition of some professional service, and it pays also a quit rent. Many of the Eenams are very curious in their objects; for instance, at th village of Wan-

gee, Pergunnah Wangee, Poona Collectorate, 15 beegahs of land to a mendicant for reading stories before the goddess Dawai at her festival; 15 beegahs to the tabor players at the temple; 30 beegahs to the tumbling and dancing women at the temple; the clarinet and double-drum players had respectively similar Eenams; the gardener, for the supply of flowers, had 30 beegahs or 22½ acres. These Eenams existed untouched under the bigoted Moosulman government, and still remain.

Surinjam.—Lands held in Surinjam involve the condition of military service: the term is of Persian origin, meaning "furniture," "apparatus," implying that the lands are to defray the expense of equipment: in fact, Surinjam is synonymous with military Jagheer. In the Poona Collectorate 181 villages appear to be alienated in Surinjam.

Doomalla.—Doomalla, in the etymology of the word, means "two rights" or "properties," from *Do* two, and *Maal* property: the term is only found in the list of villages of the Ahmednuggur Collectorate, applied to villages and lands granted to individuals, on which government has a reserved right. In this sense the tenure appears to be that of quit rent, and the term is synonymous with the Jooree Eenam of the Dharwar Collectorate. In the Ahmednuggur Collectorate 581½ villages appear as Doomalla, but this, no doubt, includes Jagheer and Eenam villages.

Eesaphut.—In the Poona Collectorate the term Eesaphut is applied to 37½ villages: it is probably a corruption from the Arabic *Zeaphut*, meaning "feast," "entertainment." Lands so held are rent free, and may have been given to assist in celebrating festivals.

In the Dharwar Collectorate the terms Jooree Eenam, Surwa Eenam, and Jagheer occur: the first corresponds to the Doomalla of Ahmednuggur, and is, in fact, a quit rent tenure; the second means "all gift," from *Surwa* "all," and *Eenam* "gift," there not being any tax or fee upon these lands: Jagheer has been explained before.

Tenure of Deshmook and Desaee.—It is a general belief that these officers were coeval with the establishment of the land institutions of the Mahratta people.* Deshmooks were the civil governors of districts, collectors of the revenue, and executive officers of the government. The name is probably a corruption of the Sanscrit *Deshuk*, a governor or ruler. In early times they were exclusively Mahrattas, and not Brahmans or Moosulmans. The importance of the office is at-

* I mean, of course, long antecedent to the Moosulman invasion.

tested by the fact that, in the earliest mention of the chiefs of the present great Mahratta families, they are styled *Deshmooks* of such and such districts. Their rights were hereditary, and saleable, wholly or in part, like those of every other hereditary office or right: the right of alienation is proved by different casts being now associated in the office. At Ahmednuggur a *third* of the Deshmookee belongs to a Brahman, and *two-thirds* to the ruling Mahratta family at Nagpoor. Similar instances are very numerous. In some cases a Deshmook is also Pateel of one of the villages in his district. The rights and emoluments of the Deshmook are very extensive, but not uniform throughout the country; they had a per centage on the revenue varying from one to five per cent. In the Poona Collectorate the mean charge for Deshmooks and Deshpandehs amounted to 3·06 per cent. of the *gross revenue*, but on the *nett revenue* it amounted as nearly as possible to six per cent; although these persons are now *non-efficient*, their authority being superseded. As a single illustrative instance, it may be as well to state, that at the village of Ankoolsur, Talook Ahmednuggur, out of a village revenue of 4533 rupees, the Deshmook received 265 rupees, and the Deshpandeh 150 rupees; the former sharing 5·84 per cent., and the latter 3·31 per cent. Their next advantage is in some of them enjoying villages in free gift; the third, in possessing Eenam land in most of the villages in their districts, sometimes to a large amount. At Mohol Talook Mohol, the two sharers in the office of Deshmook have each 450 acres of free (or Eenam) land. The fourth right of the Deshmook is a portion of grain from each village, called *Googree*, from all the land under cultivation. In addition to the above, from some villages they were entitled to a sheep and some butter annually; from some villages a dress, from others a turband, and where sugar-cane was cultivated, they had a portion of the raw sugar. They possessed the above advantages on the tenure of executing the duties previously stated. They were to a district what a Pateel is to a village.

Deshpandehs.—The Deshpandehs are contemporary in their institution with the Deshmooks; they were the writers, accountants, and registers of districts; they were always Brahmans. The terms appear to be derived from the Sanscrit *Desh*, country, and *Punnah*, to do business. They were to districts what Koolkurnees were to a village: they had, and have nearly the same rights and emoluments as the Deshmooks, but in a diminished ratio of from 25 to 50 per cent.

The offices of Deshpandeh and Koolkurnee are sometimes found united. Their duties are in abeyance, but, like the Deshmooks, they enjoy their rights.

Pateel.—The next and the most important tenure of all is that of Pateel or headman of towns and villages. Pateel is a Mahratta term, and may be derived from the Sanscrit *Puttruh*, "deed," "lease," the Pateel anciently having had the disposal of all vacant lands in his village by deed or lease. Originally the Pateels were Mahrattas, but sale, gift, or other causes have now associated in the office various casts, and there are sometimes six or seven or more sharers in the office,—Brahmans, Mahrattas, Moosulmans, Shepherds, Lingaeets, &c., and these not holding in equal proportions. I have elsewhere* given a translation of a very remarkable and curious Mahratta document, proving in the most distinct manner the right of the Pateel, not only to sell his family or hereditary property, and the lands he held in virtue of his office, but also the lands of extinct families, and his other emoluments and advantages; but, in doing so, he also alienated part of his dignity, rights, and authority as Pateel: the honours went with the lands. The rights and emoluments of the Pateel are very numerous; free land, fees of grain on the cultivation, called googree, presents on investitures, on granting letters of inheritance, on marriages; annual presents from the shoemaker of shoes, from the potmaker of pots, from the shopkeepers of cocoa-nuts, &c., market fees, *all the sheeps-heads offered in the temple of Dawai!* daily service, and supply of wood and water by the Mahr and the potmaker; precedence in all religious or other festivals, in communicating with government, and with others. The details of the translation before noticed show with what jealousy the Pateel maintained all the minutest rights and dignities. Of such importance and so profitable was the office, or in such estimation was the dignity of Pateel anciently, that princes of the Mahratta empire established themselves wholly or in part in the office in various towns and villages; *Holkur*, for instance, at Munchur; *Seendeh* (*Sindiah*) † at Jamgaon; the Nagpoor *Bhosleh* at Ahmednuggur, and *Powar* of Dhar at Multun and Kuweeteh. There are traditional accounts of a share of the Pateel's office having been sold for 7000 rupees.

The right of the Pateel to dispose of the village lands not occupied by hereditary proprietors, together with his respon-

* Journal of the Royal Asiatic Society.

† This prince has six out of seven shares in the office; nevertheless the poor Mahratta who has the seventh share has precedence of the prince.

sibility for the government revenue, involves the proof that the government assessment was anciently Mozehwar, or by the whole village, and not by direct agreement between the government agents and individual farmers. The village, in fact, was assessed at a certain fixed sum, which was called the *Tunkha,* which means an assignment; and this Tunkha appears in village accounts to this day, although no longer a standard of assessment, as the British government settles directly with the farmer, and has also abrogated the right of the Pateel and the village corporation to dispose of waste lands; in alienated villages, however, these rights remain. Although the translation before noticed gives a minute detail of the rights and emoluments of the Pateels of Kuweeteh, it is to be understood they are not uniform either in number or value throughout the country. An idea of the value of the Googree, or right to a share in the grain-produce of cultivated lands, may be formed from the fact, that at Kurjut, Ahmednuggur collectorate, in 1827, there were 8491 beegahs of land under cultivation, and the Pateel was entitled to 128 seers for every 120 beegahs; he received therefore, 9057 seers of grain, a sufficiency for the annual support of 25 persons.

The duties of the Pateel were, to be responsible for the revenue of the village, to superintend its police, and regulate its internal economy. He had power to seize, imprison, and fine offenders.

With regard to joint proprietary in the office, independently of shares being held by different casts and families, the Hindoo law of inheritance, which gives equal shares of all property to all children, necessarily made many joint owners in a family; but as the executive duties are only performed by the head of the family, this person is called *Mokuddum,* "chief" or "leader;" and the term of course is applicable to the head of each proprietary family, who is designated in the village papers as half Mokuddum, quarter Mokuddum, or seventh Mokuddum, according to the share of the Pateelship held by the family.

Koolkurnee.—The next village tenure is that of Koolkurnee, from the Sanscrit *Kool* "to count," and *Kroot* "to do," "make;" literally an accountant. The office is of very great importance, for the Koolkurnee is not only the accountant of the government revenue, but he keeps the private accounts for each individual in the village, and is the general amanuensis; few of the cultivators, the Pateels frequently inclusive, being able to write or cypher for themselves. In no instance have I found the office held by any other cast than the Brahmanical. The office is sometimes united with that of Deshpandeh, and

not unfrequently to that of Johesee or village astrologer. The Koolkurnee, like the Pateel, has Eenam land, sometimes salary, fees of grain, and miscellaneous rights of butter, raw sugar, &c., rarely having equal rights, either in number or value, with the Pateel, but commonly averaging from 25 to 75 per cent. below. Where the villages are very small, there is only one Koolkurnee for several villages, as in the case of Turruff Muhr Khor, Poona collectorate, where the duties of this individual extend to one small town and eleven villages. He is here paid by a money rate for every 30 beegahs of land under cultivation; it varies from 1 rupee the 30 beegahs to 3 rupees.

Unlike the Deshmooks and Pateels, no instance came to my knowledge of shares of the office being alienated from the family; the numerous sharers being all connected by ties of blood, who each in turn take their annual duties; and these sharers are sometimes so numerous, that at one town the execution of the duties only came to the same individual after a lapse of 20 years. The executive duties should be confined to the same person.

Mahrs Tenure.—A very important tenure in villages is that of the low-cast people, called *Mahr* by the Mahrattas, and *Dher* by the Moosulmans. They have Eenam lands in all villages, divided into *Hurkee* and *Arowlah;* the former is rent free, and generally bears a small proportion to the latter, which pays a low quit rent. The Mahrs conceive that they have the right to mortgage or otherwise dispose of lands held for the performance of specific duties to the village and the government, and numerous instances of mortgage came to my knowledge; but whether they can wholly alienate their lands or not, they *cannot* absolve themselves and their descendants from their duties: these are to cut wood and grass for government officers and travellers, to act as guides, as porters to carry baggage from village to village, and to go as messengers; they have to attend strangers and see to their wants being supplied, and if the strangers be of consequence, they or the Ramooses have to look to the safety of their baggage at night. They are the guardians of all village land-marks; they are the Pateel's messengers, (something like parish beadles,) and it is their duty to carry the collections to the treasurer of the district; they have to pass on all news or information received, whether written or verbal, whether by sign or by token, to all the surrounding villages, and it is perfectly astonishing the rapidity with which intelligence is diffused by their means. It is no uncommon thing for a distant public event to be whispered about in towns before any account of it has been received

by the government post. Occasionally the answer to my inquiries respecting the duties of the Mahrs was, that they were to do every thing they were ordered, whether by the Pateel, the village corporation, or by the government. There are many families of them in every village: in some villages they have to pay a tax to government called *Rabta Mahr*, and this is in lieu of personal service in cutting wood and grass for the officers of government, but it does not absolve them from their other duties. So strictly is it their province to cut wood and grass, that their signature to all village or public documents is a sickle or hatchet to cut grass and wood, and a rope to tie them up. In addition to their Eenam lands, the Mahrs, in virtue of their office as one of the Bara Bullooteh or twelve village officers, craftsmen, and professions, receive fees in kind from all the cultivators; the fee in kind is a per centage upon the produce, but it is not uniform in amount throughout the Dukhun. These twelve village officers are divided into three classes, according to the supposed importance of their services to the village; the first class in some villages received 50, the second 20, and the third 10 or 15 bundles or sheaves of Joaree, (*Andropogon sorghum*,) stalk and grain included upon every 1000 cut down; and the same proportion of other grains. Many farmers in various parts of the country assured me that they put by 25 per cent. of their produce for the village craftsmen and professions; and as the Mahrs from their usefulness share in all those classes, their returns must be considerable; the individual benefit depending of course upon the magnitude of the body constituting this class of persons in the village. As low casts do not cultivate their Eenam lands, they derive less advantage from them than other Eenamdars, but make the best terms they can with the Koonbees to cultivate their lands for them. The Mahr does not pay any tax to government upon his Bullooteh. In the whole of the duties of the Mahrs, whether for government, the village, or individuals, they are not bound to go beyond the village next to their own; here they hand over their charge and return.*

Bara Bullooteh Tenure.—The twelve craftsmen or professions which were originally in every village were, the *Sootar* (Carpenter), *Chambar* (Shoemaker), *Lohar* (Ironsmith), and *Mahr;* these constituted the Torlee Khas or first class. In the Mudlee Khas, or second class, were the *Pureet* (Washerman), *Koombar* (Pot-maker), *Nahwee* (Barber), and *Maang*

* In speaking of the duties of the Mahrs I ought to have used the past tense instead of the present in *some cases*, government having partly absolved them from duties, the performance of which is their tenure for holding their lands and fees.

(Skinner and Rope-maker). And in the third or Dhaktee Khas, the *Kohlee* (Waterman), *Johesee* (Astrologer), *Gooruw* (cleaner of, and attendant at the temple), and the *Sonar* (Silversmith); and, since the Moosulman rule, the *Moolana* or Moosulman priest and schoolmaster has been added. These persons, in their several lines, and according to their several abilities, were to do for the cultivators individually and the village collectively whatever might be required from them; and they were paid by an annual per-centage in kind upon the produce of the farmer; and this was called their Bullooteh, whence the term Bara Bullooteh: the fee being called Bullooteh, and the receiver of it Bullootehdar. Very rarely could I get either farmer or Bullootehdar to state specifically what the one gave, and the other was entitled to receive; it depended very much upon the crops, and also upon the extent of services performed for each individual cultivator. These craftsmen have frequently small portions of Eenam lands, and part of their Bullooteh goes to government as a tax.

Shet Sundee Tenure.—Lands were given to a kind of militia in the districts in place of pay, for the performance of certain duties, principally in the protection of their villages: this tenure is called Shet Sundee from *Shet* "a field," and *Sunnud* "a grant;" constituting the holders, in fact, a landed militia. Although this tenure may have been general at one period, I only observed lands set apart as Shet Sundee in five Pergunnahs of the Poona collectorate, and I remarked it also at Kurmulla, Ahmednuggur collectorate.

Tenure of Chowgulla.—There are several other tenures, of which a brief notice only may be given. The Chowgulla is the Pateel's assistant; he is found in most villages; sometimes he has a trifling grant of land, but most commonly grain-fees from the landholders. This personage is called Buglah where the Kanree language is spoken.

In some Turruffs a Havildar is met with; the term is of Arabic origin, from *Hawala* "charge," "custody," and *Dar* "agent," "holder." This officer was introduced by the Moosulmans as a supervisor in the collection of the revenue of a certain number of villages. He replaced the Hindoo Naik, who is still met with in some of the hill districts. The Havildar was paid by half a seer of grain from each beegah under cultivation; and for the Hindoo officer the same is levied, under the name of Naikwaree. At Kanoor, Ahmednuggur collectorate, the Naikwaree is 12 seers of grain on every 30 beegahs under cultivation.

Tulwar.—In the southern villages bordering on the Kanree tracts, I met with the village or Turruff officer called Tulwar;

but the term is unknown to the genuine Mahrattas. His duties assimilate him to the Havildar and Naik of more northern tracts.

Tenure of Ramooses.—Between the parallels of latitude 17° and 19° north, and longitude 73° 40′ and 75° E., there are few villages in Dukhun without their Ramooses. These vagabonds are thieves by birth and cast, which is abject; most of the villages have them in employ to guard the village from robbery. In some villages they have Eenam lands, but they are generally paid in fees of grain upon the cultivation. There is a perfect community of interest amongst the fraternity, however dispersed; and as they are dissipated, idle, and reckless, they not unfrequently assemble in bands, take to the hills, and commit depredations in the country, and it is necessary to chase them back to their villages by means of the regular troops. They are expert sportsmen and good shots.

Bheels.—Where the Ramooses are wanting, their places are mostly supplied by the Bheels, or by the Kohlees; the former are low casts, the latter are Shoodrahs. Their duty is to afford protection to the villages, and they have either Eenam lands or fees in grain. In many parts of the country, particularly in Khandesh, the inhabitants of entire villages, and even districts, are Bheels, or Kohlees (Coolies).

Sheteh.—Sheteh is the person by common consent admitted to be the head and spokesman of the mercantile and trading classes, in places in the districts where they are in sufficient numbers to require one; and as combination is universal, he is of some importance in the districts as their organ in regulating prices. The *Sheteh* is assisted by the *Mahajun*, which properly means a banker; but, as the colleague of the Sheteh, he is an inferior personage in the districts: both these people, in some towns and villages, have trifling Eenam lands and claims for money and grain; but on what tenure of service to the community is not very apparent.

Sur Pateel, and Sur Deshmook, and Sur Desaee.—I should scarcely have introduced any mention of the Sur Pateel, and Sur Deshmook, and Sur Desaee, as it has not come to my notice that they hold lands in tenure, but their names frequently occur in village accounts as Hukdars,* or entitled to certain rights in money, grain-fees, &c. One of the Sur Pateelships is vested in the great family of Eshwunt Rao Dabareh, of Tullegaon; and one of the Sur Desaeeships in the ancient family called Chaskur. Captain Grant Duff, in his History of the Mahrattas, makes mention of several Sur Deshmooks, and

* *Huk* "a right," and *dar* "a holder."

says, that Arungzebe allowed the old Sur Deshmooks 2 per cent. on the revenue. But the Sur Deshmookee of modern times which appears in all village accounts, was 10 per cent. of the Moghul revenue, exacted by Sewajee from the Moosulmans; it was levied over and above the land tax. The sufferers, therefore, by Mahratta violence were the Mahratta cultivators; and on the whole of the possessions of the Moosulmans coming into the hands of a Mahratta government, the Sur Deshmookee should have been abandoned, but it remains to this day; for instance, at Jehoor, near Ahmednuggur, the Tunkha, or government revenue or *assignment*, from the town was 10,817 rupees, 2 qr., 3 reas; the Sur Deshmookee 1350 rupees, 3 qr., 3 reas; but the Kumal, or total sum raised from the cultivators, including village expenses and Hukdars, was 19,363 rupees, 3 qr., 1 reas: so that the Moosulmans originally took little more than half of the revenue now raised from the town, that is to say, the Moosulmans took 10,817 rupees; then came Sewajee, the Mahratta, and wrenched from them 10 per cent. of their revenue, which should have been 1081 rupees. The Moosulmans, instead of paying it out of 10,817 rupees, clapped the demand of Sewajee upon the town as an additional burthen; and instead of honestly fixing it at 1081 rupees (10 per cent. of 10,817), they adroitly took occasion to exact a little more from their Mahratta subjects.

Many individuals have shares in the village revenues under the names of *Mokassa, Sahotra, Babtee,* and *Nargowra.* The most intelligible way to describe these, is to say that persons have money assignments, amounting to a definite per centage on the revenue, under these names. In their origin, Mokassa is 66 per cent., Sahotra 6 per cent., Babtee 25 per cent., and Nargowra 3 per cent. of the *Chout*, or fourth of the whole Moghul revenue, which was extorted from the Moosulmans by the Mahrattas. Sewajee and his chiefs shared it amongst themselves; the chiefs had the Mokassa for military services; the Sahotra was given to the Punt Suchew, one of Sewajee's ministers; the prince's own share was the Babtee; and the Nargowra, which is synonymous with Sur Pateel, or chief of all the Pateels, was at the disposal of the prince. As these grants were hereditary, the equal division of property and rights amongst children has occasioned the reduction of some of the shares to the most trifling amount where families have multiplied.

Such are the tenures that came under my notice; and it is necessary to state that, with the single exception of Surwa Eenam or "entire gift," there was an obligation of specific service on the individual or parties enjoying advantages under

the several tenures; the non-performance of these duties involved the forfeiture of their rights; but independently of such forfeiture, all grants whatever (unless specified to the contrary) were resumable by the sovereign or other grantee. Grants for religious purposes were rarely recalled; but for other objects they were frequently abrogated, particularly *Jagheer*, *Surinjam*, and *Hukdar* grants. To such an extent did this exist under the Peshwa's government, that the Hon. M. Elphinstone, in his report as commissioner, enumerates as an item of revenue, *Wuttun Zubtee*, or sequestered lands of Zumundars, which yielded annually 50,000 rupees.

Revenue.

A few figures perspicuously arranged, are more efficacious in affording just impressions of the resources of a country, their ramifications, pressure, and availability, than the most laboured verbal details. In 1827—28 the assessments in the four collectorates of Dukhun amounted to 8,435,244 rupees, 3 qr. 79 reas, being a diminution of 539,399 rupees, 2 qr. 80 reas in the revenue of Fuslee 1231, A.D. 1822, as stated in Mr. Chaplin's report; from this sum also were to be deducted the remissions of 415,000 rupees, 1 qr. 25 reas in the Ahmednuggur, and 416,320 rupees, 3 qr. in the Poona collectorate in 1827—8, amounting to a total diminution of 1,360,725 rupees, 3 qr. 05 reas, or 15·16 *decl.* per cent. of the revenue of 1822.

The revenue of 1827—28 in its constituents is shown in the following table:—

Denomination of Revenue.	Fuslee 1237.—Revenue, A.D. 1827—28.											
	Poona Collectorate.			Nuggur Collectorate.			Dharwar Collectorate.			Khandesh Collectorate.		
	rupees.	qr.	reas.	rupees.	qr.	reas.	rupees.	qr.	reas.	rupees.	qr.	reas.
Land revenue	1,516,323	...	37	1,815,837	...	...	1,945,323	2	08	1,664,904	3	32
Sahyer*	231,262	1	...	59,007	3	78	334,668	...	85	131,710	3	...
Customs	241,114	1	25	159,150	...	...	141,524	2	46	155,560	3	...
Miscellaneous	3,301	...	...	...	...	...	...	...	...	35,556	2	68
Total	1,992,000	2	62	2,033,994	3	78	2,421,516	1	39	1,987,733	...	...
Grand Total 8,435,244 rupees, 3 qr. 79 reas.												

* Sahyer is the revenue raised from shops, markets, liquors, &c. Sahyer is a "market" in Sanscrit.

From the preceding table it will be seen that in the several collectorates, although of very disproportionate superficial extent and population, in Ahmednuggur, Poona, and Khandesh there is a close approximation in the total amount of their revenues, although with some difference in the value of their great branches.

The following table exhibits the proportion per cent. of the great branches of the above revenue.

Denomination of Revenue.	Proportion per cent. of the great branches of revenue.			
	Poona Collectorate.	Nuggur Collectorate.	Dharwar Collectorate.	Khandesh Collectorate.
Land revenue	per cent. 76·12	per cent. 89·275	per cent. 80·335	per cent. 83·76
Sahyer	11·62	2·900	13·820	6·63
Customs	12·10	7·825	5·845	7·82
Miscellaneous	0·16	...	...	1·79
	100.	100.	100.	100.

There is considerable uniformity in the respective proportions of the land revenue in the different collectorates. Poona has the smallest, but it is compensated for in the magnitude of the Sahyer and customs. In Ahmednuggur the proportion of the land revenue exceeds that of Poona by 13 per cent, but this is counterbalanced by the singular smallness of the Sahyer branch. In the land revenue of Dharwar and Khandesh there is a sufficient approximation to a mean per centage for the four collectorates, which averages 82·30 *decls.* per cent. The whole revenue of England being £52,000,000, has only a land revenue of £2,000,000, or 3·846 *decls.* per cent. The whole revenue of France being £40,000,000, the land revenue is 12,000,000 or 30 per cent.

The following table shows (in 1827—28) the amount of the land revenue in each collectorate, the number of cultivators, the average rent of farms, the number of British populated villages, and the average revenue of a village: the last column is intended to show the pressure (including land Sahyer and customs) of the assessments and taxes, viewed as a capitation tax.

Names of Collectorates.	Number of British populated villages.	Average revenue per village.			Land Revenue.			Number of Cultivators.	Average rent of farms.			Land revenue, Sahyer, Customs, &c., viewed as a capitation tax.					
		rup.	qr.	rs.	rup.	qr.	rs.		rup.	qr.	rs.	rup.	qr.	rs.	£.	s.	d.
Poona	1469½	1253	1	98	1,516,323	...	37	52,668	28	3	16	4	1	78	0	8	10¾
Nuggur ...	1878½	1082	2	99	1,815,837	...	...	41,948	43	1	15	3	3	77	0	7	10¾
Khandesh	2367½	839	3	7	1,664,905	...	...	44,608	37	1	33	4	1	92	0	8	11½
Dharwar ...	2104	924	2	33	1,945,323	2	80	60,701	32	...	19	3	1	60	0	6	9½
Total	7819½	887	3	32	6,942,388	1	77	199,925	34	2	90	4	...	02	0	8	0

The population, inclusive of Sholapoor and Cheekoree and Munowlee, of the Company's possessions in Dukhun, but exclusive of alienated villages, is 2,105,886 souls, and the gross revenue 84,435,245 rupees; equal, therefore, to 4 rupees, 0 qr. 02 reas per head.

In forming the above table, the collectors were good enough to supply the number of villages and cultivators in 1827—28, and the amount of the land revenue was obtained from the Accountant-General's office. In striking the average revenue per village, I have omitted, in the division of the Dharwar collectorate, 175 villages, (subsequently reduced to 155,) which I found by the population returns lately completed were uninhabited, but parts of whose lands were under cultivation by neighbouring villagers, and therefore included by the collector in his list. In Khandesh 330 villages have been struck out under similar circumstances. In Poona and Ahmednuggur, villages of this class are very limited in number, and I have, in consequence, not made any deduction on their account.

To give a fair average of the village revenues in the Poona collectorate, 151,241 rupees, including a share of the customs, have been deducted from the whole revenue for the city of Poona previously to striking the average. The manner in which the Poona capitation tax is struck is as follows:—1108 towns and villages sent in population returns, containing 331,615 inhabitants, averaging 226 souls and a fraction to a village. The population of the city of Poona (81,315 inhabitants) being deducted before striking the average; of these villages 212½ are alienated, leaving 895½ British villages with a population of 283,567, including Poona. These in 1827—28, yielded a gross revenue of 1,261,711, averaging 4 rupees, 1 qr. 78 reas to each person.

The capitation rate in the Ahmednuggur collectorate is obtained as follows: In 1827—28, 1877½ towns and villages

were on the collector's list; they contained 494,669 souls, estimated from the average number of inhabitants to a village, namely, 263·47, struck from the census of 1822, to which the *present* population of the city of Nuggur is to be added, namely, 21,208. The revenue from the collectorate was 2,033,994 rupees, 3 qr. 78 reas; equal, therefore, to 3 rupees, 3 qr. 77 reas per head.

In Dharwar the averages have the following elements:—in 1827—28, 2279 British towns and villages produced a revenue of 2,421,516 rupees, 1 qr. 39 reas. This included the villages, revenue, and population of the Talooks of Cheekoree and Munowlee, received from the Kolapoor state; population returns were not received from these Talooks; their revenue from 225 villages, namely, 197,406 rupees, 3 qr. 29 reas, is therefore deducted from the total revenue of the collectorate, leaving 2,224,199 rupees, 2 qr. 10 reas, and 2054 villages. From the latter are to be deducted 175 depopulated villages, but having a small part of their land cultivated by neighbouring villagers, leaving 1879* British villages, with a population, agreeably to the census, of 653,892 souls, giving 3 rupees, 1 qr. 60 reas per head.

There is some difficulty in ascertaining how the revenue of Khandesh would fall as a capitation tax, in consequence of the increased number of villages (335½) rendered productive since 1825—26, (the date of the population returns,) their population not being known. In 1825—26 the inhabited villages amounted to 2032, and 330 were Pyegusta, i. e. deserted, but having part of their land cultivated by neighbouring villagers. Supposing the new villages to be peopled in the same ratio as the old ones, the number of inhabitants in the government villages in 1827-28 would have been 443,548, which is 24,031 souls more than I have put into the population returns; and as the revenue was 1,987,733 rupees, the people averaged an individual payment of 4 rupees, 1 qr. 92 reas: nevertheless, I have reason to doubt the actual increase in population to the extent I have given Khandesh credit for; and should it have remained stationary, the revenue as a poll-tax would amount to 5 rupees, 1 qr. 40 reas per head.

With respect to the branch of revenue called Sahyer, it will be seen that the different collectorates raise it in very unequal proportions. The unusual lowness of it in the Ahmednuggur collectorate is of difficult explanation. The following table shows the number of persons of each class paying this tax, the amount paid, and the average per head.

* Subsequently increased to 1899, with a population of 660,852.

Collectorates.	Number of taxable persons.		Amount of taxes.	Average per head.
	Sahyer.	Bullooteh.		
			rup. gr. rs.	rup. gr. rs.
Poona	14,551	8481	231,262 1 00	10 ... 16
Ahmednuggur	9,287	4980	59,007 3 78	4 ... 54
Dharwar.........	29,046	2811	334,668 ... 45	10 2 02
Khandesh	9,147	2348	131,711	11 1 83

It is consequently found, that Ahmednuggur, with a greater number of taxable persons in the Sahyer branch than in Khandesh, averages a payment per head of little more than one-third of what the shopkeepers, trades, and Bullooteh pay in Khandesh; and the tolerable uniformity in the individual averages of the collectorates of Poona, Dharwar, and Khandesh, proves that their Sahyer taxes are raised equitably. I have to notice, that in village papers there is a want of uniformity in the classification of the extra cesses, sometimes articles being placed under the heads of Sahyer which bear upon the land, and others again being classed with the land which are money commutations for labour.

From the definite character of the elements in the preceding table, great confidence may be placed in the correctness of deductions from it. The numbers of taxable persons in 1827—28 were supplied to me by the collectors, and the amount paid is extracted from their Jummabundy settlements for that year.

Customs.—The customs vary considerably in the different collectorates; those of Poona, being above 12 per cent. of its whole revenue, may be looked upon as high, but their magnitude manifests a favourable commercial industry. Contrary to expectation, Dharwar, which has indications of internal comparative prosperity, has the lowest revenue from customs, with a greater population, a greater revenue, and falling lighter upon the people than in any of the other collectorates, and with more than ten times the number of manufacturers * to be found in Poona and Khandesh, nevertheless shows a commercial return 52 per cent. less than that of Poona, and even 25½ per cent. below the exhausted province of Khandesh. It seems anomalous that the proportional per-centage of the customs on the whole revenue in Ahmednuggur and Khandesh should be

* Thirteen thousand and forty-five weavers.

identical, the population of the former being 23·75 per cent. greater than that of the latter, while a parity seems to exist in the wants and export resources of the people of both.

Expenses.—I have put into juxtaposition some of the items of expense in the collectorates, and their rate per cent. on the gross revenue; but the want of a systematic classification of charges under common heads throughout the collectorates, renders a rigid comparison, item for item, unattainable. The information is extracted from the Jummabundy returns of the collectors for 1827—28. A government form for this paper for common adoption would render the multitudinous details involved in it more available for comparison by inspection than in the present forms. The total expenses of two of the collectorates only is given in the following tables.

Few comments are necessary, as the charges and the rate per cent. they bear upon the gross revenue of each collectorate are seen at a glance.

TABULAR VIEW OF THE EXPENSES.

Denomination of expenses.	Expenses 1827—28.											
	Poona Collectorate.			Nuggur Collectorate.			Dharwar Collectorate.			Khandesh Collectorate.		
	rup.	qr.	rs.	rup.	qr.	rs.	rup.	qr.	rs.	rup.	qr.	rs.
Village and land expenses	136,659	...	12	149,761	2	26	...	...	...	388,016	...	...
Native establishment for collections	...	...	...	...	...	...	246,174	3	80	157,202	2	...
Mokassa	55,997	3	43	...	...	...	...	...	...	45,358	...	...
Hukdars	61,005	3	00	115,876	1	25	...	...	...	...	...	...
Contingent charges, including presents	...	...	...	101,055	3	22	190,768	3	39	339,410	3	...
Shet Sundee or native militia	34,435	2	43	...	...	...	...	...	...	...	...	...
Pensions, Eenams	...	...	...	466,493	3	89	33,522	2	94	45,619	2	24
Collector's salary	...	...	...	59,653	1	33	113,745	...	42	93,277	1	75
European Judicial	...	...	...	53,546	2	58	...	...	...	16,909	1	41
Native Judicial	...	...	...	229,366	2	73	...	...	...	90,306	...	...
Total	288,098	...	98	875,754	1	26	584,211	2	55	1,176,099	2	40
Remissions	416,320	3	...	415,005	1	25	None.			None.		
To H. H. Seendeh	...	...	...	...	...	...	...	...	...	90,796	3	33

TABULAR VIEW OF THE PROPORTION PER CENT. OF EXPENSES.

Denominations of expenses.	Proportion per cent. of the expenses on the whole revenue in the several Collectorates.			
	Poona Collectorate.	Nuggur Collectorate.	Dharwar Collectorate.	Khandesh Collectorate.
	per cent.	per cent.	per cent.	per cent.
Village, land and Sahyer expenses	6·86	7·36	...	19·52
Native establishment for collections	...	...	10·17	7·92
Mokassa	2·81	...	...	2·28
Hukdars	3·06	5·70	...	...
Contingent charges	...	4·96	7·87	17·08
Shet Sundee, militia	1·73	...	...	...
Pensions, Eenams	...	8·18	1·39	2·29
Collector's salary	...	2·93	4·69	4·67
European Judicial	...	2·63	...	0·85
Native Judicial	...	11·27	...	4·52
Total	14·46	43·03	24·12	59·13
Remission	20·89	20·40	None.	None.
Grand Total	35·35	63·43	24·12	59·13

For the proper understanding, however, of some omissions in the above abstracts, short notices are called for.

Under the items of "village, land and Sahyer expenses," "Shet Sundee," "Mokassa," and "Hukdars," there are blanks in the Dharwar collectorate, the whole land expenses amounting to 24·12 per cent.; it is to be presumed the charges under these heads have merged in the "Native establishment for collections." Under Khandesh there is a blank for the Hukdars; the expense of these persons is no doubt included in "village, land, and Sahyer expenses." Under Nuggur there are blanks under "Mokassa" and "Shet Sundee;" they must be included in the "Land and village expenses." Of the omissions in the Poona abstract it is unnecessary to speak, as they are intentional.

The charges, revenue, magisterial, and judicial, upon the revenue of Ahmednuggur in 1827—28, amounted to 43·03 per

cent., and remissions were granted in that year to the amount of 20·40 per cent.; the total deduction from the revenue was 63·43 per cent. In Khandesh, without any remissions, the charges were nearly six-tenths of the whole revenue. In Poona I have only shown the charges which are strictly and permanently fixed upon the land in all the collectorates, which are not mutable, and therefore scarcely susceptible in justice of modification; these amount to 14·46 per cent: they comprise village expenses, militia, Mokassa, and Hukdars. In Dharwar, the collector's establishment has been added to the above, and it brings the charges strictly bearing on the land to 24·12 per cent. on the revenue.

A review of the above tables and abstracts suggests the following observations. The collectorate of Dharwar, having the smallest area[a] (with the exception of Poona) of the collectorates of Dukhun, has the greatest population, and produces the greatest revenue, which bears lightest by average upon the inhabitants individually.[b] Judging from the lowness of the customs, it has the weakest indications of commercial industry; nevertheless, the manufacturers, particularly the weavers, exceed those of the other collectorates in the ratio of 100 to 11, or 89 per cent. The shopkeepers and tradespeople are very numerous, and their individual taxes[c] rise to the average of those of Poona and Khandesh. Finally, the means of the people (remissions not being called for) must be more efficient than in the other collectorates, and a proportional ratio of imports and exports might have been looked for.

Khandesh has the largest superficial extent,[d] a population[e] 29 per cent. less than that of Poona, or granting an increase to its population 15·32 per cent. less, with a revenue nevertheless equal to that of Poona, bearing in consequence with unusual pressure upon the people, its average being 5 rupees, 1 qr. 40 reas to each soul; involving the fact that the assessments in this collectorate are greater than in any of the others. Admitting, however, the estimated increase to the population previously noticed, (which certainly exceeds the truth,) the average[f] individual payment will still exceed that in the other collectorates. It is possible this apparent pressure may be

[a] 9122 square miles, including the cultivated area of the Talooks Cheekoree and Manowlee.

[b] 838,757, including the estimated population of the Talooks of Cheekoree and Manowlee, 3 rupees, 1 qr. 6 reas per head.

[c] 10 rupees, 2 qr. 2 reas.

[d] 12,527 square miles.

[e] 371,404, but supposed this year to be 443,548 in government villages.

[f] 4 rupees, 1 qr., 92 reas.

referred to the extent of its garden cultivation, which is much greater than that of Dharwar, and, as far as I can judge from observation, that of Poona and Ahmednuggur also. In Khandesh in 1826, there were 82,697 beegahs[a] of garden-land, being 9·36 per cent. of the whole cultivated land, the garden-land in Dharwar not amounting to one-half per cent. In the Nuggur and Poona collectorates, in the towns of Kurmalleh, Kurjut, Angur, and Rawgaon, the proportion of garden to field-land in cultivation was 5·45 per cent. only. But, under all circumstances, the villages of Khandesh average[b] the least revenue in Dukhun; it stands third in the number of its cultivators,[c] but second in the amount of the rent of its farms.[d] The magnitude of this rent, it is inferred, originates in the comparative high rate of assessment per beegah, and not in the greater size of the farms. I have not the number of beegahs of land in cultivation in 1827–28 in Khandesh, but justify my inference from the following data:—In 1826 there were 37,311 cultivators, and 883,548 beegahs under cultivation, averaging 23·68 beegahs to each farm.[e] Last year, there were 44,608 cultivators, and supposing them to hold individually the average number of beegahs of 1826, the result will be as

$$\overset{\text{cult.}}{37{,}311} : \overset{\text{beegahs.}}{88{,}348} :: \overset{\text{cult.}}{44{,}608} : \overset{\text{beegahs.}}{1{,}056{,}345};$$

and as the land revenue of 1827–28 was 1,664,904 rupees, the rate per beegah is therefore 1 rupee, 2 qr. 30 reas,[f] which exceeds[g] that of the other collectorates from 50 to 100 per cent.

In the Sahyer branch of revenue the increased pressure is still visible upon the people; it exceeds the mean pressure of Dharwar and Poona 10·35 *decl.* per cent., and that of Ahmednuggur in the extraordinary ratio of 63·91 per cent.

The customs' per centage on the whole revenue is identical with that of Ahmednuggur, although, in the present state of Khandesh, it could not have been looked for.

Ahmednuggur stands second in superficial extent.[h] The land revenue is only inferior in amount to that of Dharwar, although it has the least number of cultivators[i] in all the collectorates. The average rent of farms therefore is the greatest;

[a] 62,023 acres. [b] 839 rupees, 3 qr., 7 reas. [c] 44,608.
[d] 37 rupees, 1 qr., 33 reas.
[e] $\frac{\text{Beegahs } 883{,}448,}{\text{Cultivators } 37{,}311.} = 23{\cdot}68.$ [f] $\frac{\text{Rupees } 1{,}664{,}904}{\text{Beegahs } 1{,}056{,}345} = \overset{\text{ru. qr. rs.}}{1\ \ 2\ \ 30}$ per beegah.
[g] Poona and Nuggur 3 qr. 58 reas per beegah, including garden-land. The whole of Dharwar 2 qr. 94 reas per beegah, including garden-land.
[h] 9910 square miles. [i] 41,948 cultivators.

and from averages struck in different villages in various parts of the Desh in this collectorate, I would refer it to the increased size of the farms rather than to enhanced assessments.

In a table, which will be met with in treating of the condition of the people, farms are made to average about 45 beegahs each; and the assessments, including extras, do not amount to a rupee per beegah.[a] In the hilly tracts the farms are necessarily much reduced in size, and an average for the whole collectorate would bring them down probably to 35 beegahs each; 41,948 cultivators therefore would occupy 1,468,180 beegahs of land, which, divided into the land revenue, (1,815,837 rupees,)[b] give 1 rupee, 95 reas per beegah. I am rather disposed to rely upon the general average, than upon the average struck from the examination of the papers of a few towns in the most favourable parts of the country.

The very low amount of the Sahyer, which is only 2·90 per cent. of the whole revenue, has been already adverted to. The taxable persons,[c] nevertheless, under this head, exceed those of Khandesh.

The customs bear a fair proportion to the whole revenue.

The average revenue[d] per village may be subject to a slight modification, as in the number of British villages, amounting to 1878½, furnished to me by the acting collector, which paid revenue last year, deserted villages are not distinguished, part of whose lands are under cultivation; and the want of population returns disables me from ascertaining them.

The revenue, viewed as a poll tax,[e] bears easier than in any other collectorate, excepting Dharwar. The means to insure an approximate accuracy in this calculation have been already explained.

Poona has the smallest land revenue, and the smallest superficial extent.[f] Previously to the addition of the four Talooks of Sholapoor, Mohol, Moodeebeehall, and Indee, agreeably to information furnished by the Survey Department, it comprised an area of 4990 square miles only. Neither the extent nor population of these Talooks being known, it was necessary to estimate them; the process was conducted by analogy, which has been explained elsewhere; 2888 square miles

[a] 2*s.* 8*d.* per acre.

[b] $\frac{\text{Rupees } 1{,}815{,}837}{\text{Beegahs } 1{,}468{,}180} = \overset{\text{rp.}}{1}\ \overset{\text{qr.}}{0}\ \overset{\text{rs.}}{95}$ per beegah.

[c] 14,267.

[d] 1082 rupees, 2 qr. 99 reas.

[e] Revenue as a poll tax, 3 rupees, 3 qr. 77 reas.
Area 7878 square miles.

resulted from the calculations, giving the Poona collectorate an area of 7878 square miles. Poona has the greatest number of cultivators[a] excepting Dharwar; and this is to be attributed, not to the extended cultivation, but to the Mawul, or hilly tracts, occupying a great deal of the collectorate, where the farmers are multiplied and the individual agricultural operations of very limited extent. In the whole Turruff of Mhurkhoreh the farms average only 13 beegahs each;[b] but in the eastern and south-eastern parts of the collectorate they have the same average as is given to Ahmednuggur. From the above facts the farms might be expected to average a very low rent, as is found to be the case. The following estimate justifies the inference that the land assessments are comparatively not very onerous.

In the Desh, or Table Land, the farms average . .	45	beegahs.
In the Mawuls, or hilly tracts	13	do.
	2)58	
Mean average of farms	29	beegahs.

In 1827–28 there were 52,668 cultivators, which multiplied by 29, the average number of beegahs to each farmer, will give 1,527,372 beegahs of land under cultivation; and as the land revenue of 1827–28 amounted to 1,516,323 rupees, 37 reas; the assessments would only be at the rate of 3 qr. 97 reas per beegah,[c] including garden land and extras. There are still however some marked features which are not satisfactory: the villages average a greater revenue (excluding the city of Poona) than in the other collectorates, although the average village population is less for that part of the Poona collectorate, whence population returns have been received.

The 574 villages of the sub-collectorate of Sholapoor average 1272 rupees, 1 qr. 12 reas each,[d] including customs. The magnitude of the average of the remaining villages may be attributed to the great amount of the customs;[e] but deducting a suitable proportion of the customs[f] for the inhabitants of the city of Poona,[g] and the whole of the revenue of the city, Sahyer,[h] land,[i] and Abkauree,[k] and mint[l]; villages (always excluding the four talooks of Sholapoor) still average 1241 rupees, 1 qr. 76 reas

[a] 52,668. [b] $9\frac{3}{4}$ acres. [c] $\frac{\text{Rupees } 1{,}516{,}323}{\text{Beegahs } 1{,}527{,}372} = 3$ qr. 97 reas per beegah.

[d] Revenue of sub-collectorate of Sholapoor 730,289 rupees, 1 qr. 93 reas.

[e] 215,361 rupees, 2 qr. $37\frac{1}{2}$ reas. [f] 61,756 rupees, 1 qr. 63 reas.

[g] 81,515 inhabitants. [h] 56,202 rupees, 3 qr. 50 reas.

[i] 27,981 rupees, $81\frac{1}{2}$ reas. [k] 12,000 rupees. [l] 3301 rupees.

each, which is higher than in any other collectorate; and as the villages in this part of the collectorate average a fraction more than 226 inhabitants,[a] the taxes, assessments, and customs,[b] after deducting the share for Poona, 151,241 rupees, fall upon the people with the unexampled pressure of nearly 5½ rupees per head,[c] while the people in the city[d] average only 1 rupee, 3 qr. 44 reas per head, including a proportional share of the customs, and the city, Sahyer, and land-tax, &c.

For the whole collectorate of Poona, including the four talooks of Sholapoor, by a process previously explained, the assessments average 4 rupees, 1 qr. 78 reas per head, which closely approximates to that of Khandesh.

Poona has the greatest number of taxable persons[e] after Dharwar in the Sahyer branch of the revenue, and ranks second in the total amount of the sum raised, which falls with a less pressure individually than in Dharwar and Khandesh, but greater than in Ahmednuggur. The manufacturers, as contributors to the Sahyer, are very limited in number.

The proportion that the customs bear to the whole revenue is a very striking feature: they are derived principally from imports, a good part of which passes on to the eastward; much is consumed in the city of Poona, and the rest is dispersed into the districts. I have observed that imports from the coast have gradually cheapened in their retail price within the last three or four years, owing, no doubt, to the combined causes of increased importation and scarcity of money in Dukhun.

The collectorate of Dharwar, whether viewed with respect to the quantity of land under cultivation; the size of its farms;[f] the amounts of its revenue; the lightness with which it falls upon the people, considered as a poll-tax;[g] the magnitude of its Sahyer; the comparative denseness of its population; its numerous towns[h] and tolerably well-peopled villages; the facility offered for instruction in the number of its schools, and the manifestations of manufacturing industry in its numerous weavers,[i] is unquestionably the finest British province in Dukhun.

Dharwar Land Revenue.—The land revenue, in its proportion to the whole revenue, stands third in the Dukhun collectorates, being 80·336 per cent.; but this apparently inferior station is to be attributed, not to the diminished quantity of

[a] 894½ villages with inhabitants, 202,252. [b] 1,110,470 rupees.

[c] 5 rupees, 1 qr. 96 reas.

[d] Inhabitants of Poona 81,315. Taxes and proportionate share of customs &c. 151,241 rupees.

[e] 23,042. [f] 32·74 acres, or 43·65 beegahs. [g] 3 rupees, 1 qr. 60 reas.

[h] 119. [i] 13,345.

land under cultivation,[a] which far exceeds that in the other collectorate, (i. e. 61·11 *decls.* per cent. of the whole lands, leaving only 38·89 *decls.* per cent. of waste,) but to the lowness of its land assessments, amounting only to 2 qr. 94 reas per beegah, including all extras falling on the land. The process by which this average assessment was struck is as follows. In 1827, agreeably to the population returns, the land in occupation of a cultivator averaged 32·74 *decls.* acres, or 43·65 *decls.* beegahs; in 1828, in the Jummabundy settlement, there were 60,701 cultivators, which, multiplied by 43·65 *decls.* gives 2,649,598. 65 *decls.* beegahs of land under cultivation. These divided into the land revenue, 1,945,323 rupees, 2 qr. 8 reas, give 294 reas per beegah, a low rate, which neither the examination of village accounts, nor a similar process, will give in Poona, Ahmednuggur, nor Khandesh.[b] This light assessment, equal only to 1*s.* 11½*d.* per acre, is certainly advantageous in insuring the realization of the revenue; but when put into comparison with the rent of land in England, shows the unproductive and limited character of Indian agricultural resources.

The Sahyer branch of the revenue is highly favourable, amounting to nearly 14 per cent. of the whole, and, though so productive, falls as a tax lighter on individuals than in Khandesh. The customs, being 2 per cent. lower than in Khandesh and Ahmednuggur, is at variance with the tolerably efficient character of the general resources of the Dharwar.

From the examination of village papers I find that remissions were very rare under native governments, and the facility with which they are granted under the British government, and their magnitude, testify strongly to its paternal character. Great caution, however, is requisite in granting them, not less on account of the government than on account of the cultivator himself. If obtained with facility, and without rigid and sharp examinations, and some personal inconvenience to the applicant, (from the habitual indolence of the native character,) his ordinary industry, which always requires stimulating, would be paralyzed, applications multiplied, labour diminished, and the farmer would trust to the forbearance of government rather than to his own exertions. There is another reason for caution in the strong motives that the native agents have for urging remissions, with a view to intercept them in the transit of accounts through their hands.

The collector cannot possibly personally ascertain the truth of

[a] 2,308,064 acres in 1827.

[b] Ahmednuggur 1 rupee, 95 reas; Nuggur and Poona, partial average, 3 qr. 58 reas; Khandesh 1 rupee, 2 qr. 30 reas per beegah.

one-hundredth part of the claims set up; he must leave this labour to his servants, and it can scarcely be believed they will not avail themselves of the opportunity to turn the discretion given to them to private profit; in fact, I know such to be the case.

In an examination of the papers of the villages of Muhrkoreh, Poona collectorate, I found that many of the cultivators had paid instalments of their assessments (for 1827–28) previously to remissions being granted, which exceeded the amount they were required to pay after the deduction of the remissions; the poverty of some of the cultivators, consequently, must have been misrepresented. I ascertained also that part of the remissions of 1827–28 had been intercepted. Remissions are unavoidable in all calamitous visitations of Providence, which are not of confined or local operation, and which affect the returns of the earth; but to insure the benefit of the remissions to the cultivator, they should be made in a definite per centage on his total assessment, and the amount should be proclaimed more than once, and by different persons, in the public place of every village.

A few words in conclusion will suffice with respect to the great branches of the revenue. It is seen that 82·30 *decls.* per cent. of the whole is derived from the land: already the supply of agricultural produce exceeds the demand, and the farmer has a difficulty in finding a mart. In the present state of agriculture therefore, this branch of revenue is at its maximum, and will probably decline until supply and demand be adjusted.

The prospects of improvement in the Sahyer branch are not more favourable than in the land revenue.

The trades pay to the full extent of their means at present, and manufactures cannot increase when the European importers of cottons can afford to undersell the native manufacturers. Indeed I believe little more than coarse Sarhees[a] for women, and common tent cloth, are now manufactured in the British provinces in Dukhun.

The improvements in customs should usually depend upon increased wealth and commercial industry in the people. The extent of imports will only be commensurate with the means of purchase. If therefore the opinions I have advanced on the land revenue and Sahyer be well founded, with respect to the limited means of persons paying taxes under those heads, the customs will be influenced by causes affecting them.

Any general improvement in the revenue would seem to require the creation of exportable articles in agriculture, horticulture, or manufactures; and to effect this desirable

[a] Dresses.

object, the introduction of persons with capital, enterprize, ingenuity, commercial tact and industry, is necessary; essentials, of which the country is at present destitute.

The manner in which the revenue yielded by a village is partitioned, is well exemplified in Neembawee, Pergunnah, Kurdeh, Ahmednuggur collectorate. The village is in Jagheer to Bala Sahib Rastea, one of the great Jagheerdars. The shares in the village are called amuls[a], and there are six of them; Rastia has three, Suchew[b] Punt one, and the Honourable Company two. The whole shares are considered as an integer of 123 parts.

Sun, 1236.—A.D. 1826.

Rastia has the Jagheer[c]	50	
Sur Deshmookee and Nuzzur[d]	23	
Kussur,[e] or remainder	7	
		80
Suchew Punt has the Sahotra	23	
		23
The Honourable Company has the Mokassa	15	
and the Neem Chowthaee, or half of the tribute called "Fourth"	5	
		20
Total		123

In addition, the fixed money rights on the village are—

	Rupees.
Sur Pateel Dabaree of Tellegaon	5
Kundeh Kurdehkur Deshmook	101
Amrut Row Joonurkur Deshpandeh	101

Besides the Pateel and Koolkurnee, Chowgulla, Bullooteh, who have their fees.

It would seem very desirable to abolish the above absurd verbal distinctions, and to fix the rights of individuals as simple money dues, without reference to Jagheer, Nuzzur, Kussur, &c.

The revenue of Dukhun, contrasted as a capitation tax, with that of England, France, and America, would appear to be as follows. In England, the gross revenue of 1828 was £50,700,000; poor-rates, parish rates, lighting, watching,

[a] Amul, "rule," "sway."

[b] Suchew, "friend," "minister;" one of the eight ministers of the Rajah of Sattara.

[c] A fief.

[d] Nazar, "sight," "look," a present made on introduction to a person.

[e] Kasr, "a fraction."

£12,000,000; contributions of congregations to their clergy, colleges, schools, &c. about £17,300,000: total £80,000,000 [a]. The population being 20,000,000, the tax per head is £4. In France, the taxation, including provision for the clergy, schools, &c. is £40,000,000; the population 30,000,000; equal therefore to £1. 6*s*. per head. In America the population is between 10,000,000 and 11,000,000, and the taxation £5,000,000, or not quite 10*s*. per head. The revenue of Dukhun, viewed as a capitation tax, is 8*s*. per head.

Assessments.

Assessments and land measurements are so intimately connected, that it would not answer any good purpose to treat of them in separate sections. With respect to the portions of land variously denominated for the purpose of assessment, I am clearly of opinion that the prevailing denominations amongst the Hindoos were not descriptive of superficial extent, and that the assessments were founded on the productive power of the land without reference to its quantity, and were uniform only for similar denominations of land in a village.

The Moosulmans, no doubt, endeavoured to be more systematic; they measured garden lands, and probably in some few villages, the field lands, under the denominations of Kundhee, Mun, Tukeh, Piceh, Seer, &c. with a view to the general conversion of such terms into the uniform and appreciable term of Beegah; but the Hindoo terms not applying to quantity, the beegahs of different villages could only be equal when there existed an accidental identity in productive power in the *unmeasured* Mun or Kundhee, &c. of land in one village with the *measured* Mun, Kundhee, &c. intended as common types. This will account for the varying extent of the beegah in field cultivation in Dukhun. How little successful the Moosulmans were in their attempt to supersede the old terms, is proved in the limited extent to which the assessments by beegahs obtained when we took possession of the country. It may be well doubted whether we shall be more successful in our introduction of acres: the ramifications of ancient usages amongst a people are in general too deeply fixed to be eradicated by legislative enactments. A plant may be cut off by the surface, but there is always a latent disposition to reproduction from the untouched roots. Whatever may be our success, a revenue survey was imperatively called for under the indefinite Hindoo land denominations, to enable a collector to regulate his assessments with a shadow of equity.

[a] Speech of Colonel Davies in the House of Commons, May 8, 1829.

With respect to the denominations under which land is assessed in the comparatively limited space of my inquiries, their variety and absurdity demonstrate a wanton *bizarreness* that could scarcely have been looked for in a people reputedly simple and uniform in their opinions and economy. The assessment on a beegah is definite as it depended on positive measurement, and I have remarked that it obtains at, and in the neighbourhood of the established seats of Moosulman authority, as at Ahmednuggur, Purunda, Sholapoor, Mohol, Barlonee, Wamoree, Tacklee, &c. The Chahoor and Rookeh, as at Alkootee, Kheir, Wangee, Taimbournee, Kurkumb, Angur, Mahreh, Kurmalleh, Kurjut and Meerujgaon, being multiples of the beegah, are intelligible. Even the Doree or rope, used at Hungawarreh and Neembee, as it implies measurement and superficial extent, is admissible. The old Hindoo terms, Kundhee and Mun, at Ranjungaon, Jamgaon, Parnair, &c. &c. as they are founded on positive properties, furnish sufficiently precise ideas. But the Tukeh, with its constituents of Sujgunnees and Piceh, (copper coin,) at Dytna and Ankolner, the Seer of weight and its Nowtanks or $\frac{1}{8}$ Seer, as at Koorul and Wangee, and the Pyhnee and its Annas[a] at Serrolee, Bruhmunwarreh and Muhr, are not reducible by any operation of the mind to an appreciable portion of land, whose produce shall admit of the government share on it being equitably assessed. The assessment by the hatchet, rude as it is, still involves the idea of as much copse-wood land as one hatchet can clear, and one man can sow and reap in the year. To add to the confusion, similar denominations of land are not made up of common and uniform constituents. The Tukkeh at Kothoul is raised from the Rookeh, each of which is supposed to contain 10 beegahs, or $7\frac{1}{2}$ acres. At Ankolner the Tukkeh is composed of Sujgunnees, Piceh and Rookeh; the Rookeh being equal only to $2\frac{1}{2}$ beegahs, or $1\frac{7}{8}$ acres. At Lakungaon there are 10 Tukkeh to one Pyhnee, and as the Pyhnee is said to contain 30 beegahs, the Tukkeh here contains only 3 beegahs instead of 480, as at Tellegaon; or 240, as at Ashtee.

In respect to the Mun at Ranjungaon, it is rated at 10 beegahs; at Jamgaon, belonging to Seendeh, it is not reducible into beegahs at all; at Parnair $6\frac{1}{4}$ beegahs only are equal to the Mun. The Pyhnee at Seerolee has the Chahoor of 120 beegahs as a typical standard, 4 Pyhnees being equal to one Chahoor, or 120 beegahs; at Muhr the Pyhnee of 30 beegahs is considered as identical with the Kundhee of 20 Muns, reducing the Mun therefore to $1\frac{1}{2}$ beegahs.

[a] One-sixteenth of a rupee.

Under such complex definitions and involved contradictions, my limits will not permit me to give further explanations, but which my lengthened tables afford.

The principal assessment necessarily falls on the land, and it is raised on the various land denominations above noticed; the land in the first instance being separated into the two great classes of Bhaghaeet, or garden-land; and Zerhaeet, or field-land. Both these terms are evidently of Moosulman introduction, Bhaghaeet being a word of Persian origin, meaning "gardens," "orchards;" and Zerhaeet, of Arabic derivation, meaning a "sown field," "sown land."

There are marked traces of the land assessment having once been systematic in the Sostee or permanent rate, which was uniform and unchangeable for all lands of the same denomination. This rate is found in most villages, it is distinctly stated in the accounts, and separated from subsequent and increased assessments, and its existence is a proof that assessments formerly were not on the superficial extent, but on the productive power of the soil; since, as lands were not all equally fertile, more of the unfertile land must have been held than of the fertile, to enable the cultivator to pay a fixed sum in quantity of grain for a piece of land under a common denomination. The *Sostee Dur*, or permanent assessment, was the pride of the Meerasdar, but unhappily not his safeguard. The various governments which have passed away do not appear ever to have *raised the permanent rate*, but they rendered the advantages derivable under it abortive from gradually adding extra cesses; their excuses in the first instance being unlooked-for contingencies. The cesses were originally mostly in kind, and temporary; but the exigencies of government, or the facility with which they were raised, made them perennial, and their pressure upon the cultivator has been enhanced, particularly under our government, by the cesses in kind being commuted into money payments. The Moosulmans, on introducing measurements, must necessarily have subverted the Sostee, or uniform rate, since the same rate could not have been equitable for beegahs of land of different qualities. We find, in consequence, that when the lands are classed in beegahs otherwise than as constituents of Hindoo land denominations, that there the assessments are on the quality of the soil, and vary accordingly.

Gardens being dependent on the local advantages of a suitable supply of water and some depth of soil, usually met with in hollows or on the banks of rivers, it might be expected that considerable uniformity would prevail in the quality of garden-

land, and that it would rarely be divided into classes; such is usually found to be the case. Most commonly all garden-land appertaining to a village pays the same rate per beegah; and where classification exists, it is founded, not on the quality of the land, but on the extent of the supply of water.

The first great feature, in this respect, is whether the garden is watered from small streams conducted from rivulets or rivers, or whether it is watered from wells; in the former case it is called Paatsthul,[a] and in the latter Mohtsthul.[b] Most Pahts failing in the dry months of March, April, and May, the former land is usually assessed at a lower rate than the latter, as at Tellegaon and Parnair; but where the Paht supply is perennial, as at Dytna, both descriptions of land pay the same rate. Dependent on these primary distinctions, are modifications, affecting garden assessments: land with a perennial and sufficient supply of water, whether from pahts or wells, is called Wohol-Waho, or fully watered, and pays the highest rate; this rate, unless on rice land, and isolated spots, where fruits of considerable value are raised, such as grapes and golden plantains, &c., as at Joonur, within my observation, has never exceeded 6 rupees per beegah,[c] including sugar-cane land. The other classes of land are comprised in the Kord Waho or not fully watered. It is readily intelligible that a well may supply a sufficiency of water for great part of a garden within a reasonable distance of the well, but that the extremities may be inadequately watered, and this affords just grounds to demand a lighter tax for the extremities: two classes should result from such circumstances, i. e. fully watered and not fully watered, and such is generally the case where distinctions are made at all: but at Ahmednuggur there is an affectation of discrimination, which has determined that garden-land receives its watering in the proportions of "fully," "thirteen-twentieths," "three-fifths," and "one-half," and such lands are respectively assessed at 5 rupees, $3\frac{1}{4}$ rupees, 3 rupees, and $2\frac{1}{2}$ rupees per beegah. The assessment on garden-land at present is unequal, and the whole requires revision. There is every motive to make garden-cultivation assessments light with a view to insure to each cultivator, if possible, his well and little plot of garden ground. Gardens produce all the year round; they are comparatively unaffected by the droughts which destroy field crops; and independently of the constantly saleable garden stuffs, fruits, and aromatic seeds, there is usually room for a beegah or more of bukshee or johr

[a] From Paat "a channel," and Sthul "a field."
[b] From Moht "a water-bucket," and Sthul "a field." [c] 16*s.* 8*d.* per acre.

wheats, which require watering, and a plot or two of sugar-cane. To his garden the cultivator is indebted for many of the little enjoyments his situation is susceptible of. In some instances, in the Mahloongeh Turruff, Poona collectorate, I found cultivators paying their entire assessments, and reaping profit by their garden produce of chillies[a] alone, which were sent into the Konkun.

Usually it has been deemed sufficient to arrange Zerhaeet or field-land into four classes, as at Jehoor, namely, Awul (best), usually black land, Rehsee (modified black), Burrud (dashed with lime and some decomposing greenstone), and finally, Khurrud (stony, thin, and poor). The first, throughout the country, does not average more than 1 rupee the beegah, the second $\frac{3}{4}$, the third $\frac{10}{16}$, and the last $\frac{8}{16}$ of a rupee per beegah; but at other places there are other distinctions. In the Mawuls, or hilly tracts along the Ghauts, lands are classed as Bhat, Khatan, and Wurkus, the first being rice land, the second wheat and grain land, and the third being on the slopes of hills, producing the dry grains Sawa[b] and Wuree;[c] there being a great deal of red soil also in these tracts, it is distinguished by the term Tambut or copper-coloured. The Awul, or best, where it occurs, is called Kalwut (black), and the rocky and stony Maal.

These explanations are sufficient to show that where assessments on the quality of the land have been introduced, uniformity has not obtained in distinguishing the qualities; they show also that the people were satisfied to limit the qualities to four gradations; but at Ahmednuggur, the Shaikdar or inspector of cultivation has had the microscopic ability of vision to mark twelve shades of difference in the field-land. The accounts are, in consequence, a mass of perplexity, and it is very probable the revenue is frittered away in distinctions which the cultivator never dreamt of, and never profits by.

Field-lands, on which the cultivators sink wells, are not assessed as garden-lands. At Kanoor, Nuggur collectorate, I found lands so circumstanced had been free from any extra assessments from a period beyond the memory of man.

The above notices are sufficient to show the anomalous character of the money assessments strictly on the land. Not only are they arbitrarily fixed on the productive power of the land, or on measurements, real or supposed; but lands of the same denomination and quality are differently assessed in neighbouring villages without apparent cause.

[a] Capsicum annuum, and other species.

[b] Panicum frumentaceum. [c] Panicum miliare.

The average of all the rates at many towns and villages in all parts of the country, derived from personal inspection of the village accounts, gives 3 rupees, 41 reas for a beegah of garden-land, or 8*s*. $3\frac{1}{3}$*d*. for an English statute acre. The average of field-land is 3 qr. $93\frac{3}{4}$ reas per beegah, or 2*s*. $7\frac{1}{2}$*d*. per English acre.

To determine an approximate average assessment per beegah in Khandesh, I may use elements, which although not just, may be expected to give results not very far from the truth; namely, the total number of beegahs of land under cultivation in the population returns in 1826, and the land revenue in 1827–28: the former is 883,548 beegahs, and the revenue 1,664,904 rupees: the average rate per beegah is 1 rupee, 3 qr. 54 reas, a much higher rate than exists in the other collectorates.

These assessments comparatively with those of all European countries, of most Asiatic countries, and relatively to the valuable nature of the garden produce, comprising, independently of the ordinary fruits and vegetables, grapes, oranges, sugar-cane, cotton, two kinds of fine wheat, and aromatic and pungent seeds,—the field produce also embracing all the bread grains, gram, and other pulses,—are unquestionably very low; and were there no extra cesses even in the present depreciated value of agricultural produce, could not only be borne by the cultivator, but he might flourish under them even with the burthen of 25 per cent. on his produce—fees paid to the Hukdars and Bullootehdars. These rates, however, are considerably enhanced by extra cesses called Puttees, many of which were levied for contingencies and particular exigencies, or resulted from the conversion of voluntary offerings in kind into compulsory money payments.

These cesses are no less than 62 in number in the three collectorates of Poona, Ahmednuggur, and Khandesh, and the whole of them are for different objects; many of them result from local circumstances, and are therefore of a local bearing. The majority of these Puttees are not of uniform operation in the three collectorates, but one or more of them up to a score may be found in every village.

A few observations on the origin, character, and practical effects of some of these Puttees may be necessary. Most of them profess to bear directly on the land, such as those for grain, forage, and ropes to government, grain to Ramooses, Havildar, Gosawees, and Meeras tax, tax for sugar, &c.: other taxes which originally fell upon tradespeople, such as those for skins, shoes, wool, blankets, and oil, are no longer derived from their legitimate sources, but fall upon the cultivator.

Milch cattle, fowls, mango trees, and pumpkin beds respectively continue to supply the means to pay the taxes for Ghee, thickened sour milk, fowls, and fruits. Some of the Puttees involved personal labour, such as those for grass cut and furnished gratis to government, for firewood, for dinner plates composed of leaves sewn together, for monsoon great coats made of wicker work and leaves, and for sticks to pound rice with. The Rabta Mahr, spoken of under "tenures," is in lieu of personal services. Some of them in their name indicate their professedly temporary character, such as the Eksalee, or for one year, and yet they have been perpetuated. The Shadee or marriage cess at Angur, Pergunnah Mohol, and Ashtee Pergunnah Oondurgaon, amounted to nearly 12 per cent. of the whole revenue of the towns, and could only have been for a passing event. The Wurgut at Wangee and Ashtee, which was raised by the village authorities for village expenses, is one of these unjustifiable taxes. At Ashtee, the scene of the battle of Ashtee and capture of the Sattarah princes, in 1818, the Wurgut was 1405 rupees, in a revenue of 6386 rupees, or 22 per cent.; of this sum government took 900 rupees, leaving 505 rupees to the villagers for their expenses. This Puttee at the town of Kurjut, Pergunnah Kurreh Wullet, is 6 annas per rupee, or 37½ per cent. on the land and Sahyer assessments, and Burgoojur or tax on betel gardens. At Rawgaon, the Wurgut amounted to 14½ annas per rupee on the land assessments and taxes, or more than 90 per cent. The Kaateh Mornawul, or pecuniary punishment, inflicted on a village for a Mamlehdar's running thorns into his feet on perambulating its lands, should have had some limits in its duration. The Puttees for sturdy Gosawees, Havildars, Ramooses, Naikwarees, should have ceased when there were no longer Gosawees to beg with arms in their hands, or Havildars, Naiks, and Ramooses to exercise respectively certain functions.

The fractional apportioning the above taxes to the cultivators, involving also the compound operation of providing reduced shares for the privileged classes, the fractional deductions, in a certain ratio in case of remissions, the fluctuating amount of the individual shares dependent on the fixed commutation cesses, being yearly divisible amongst a variable number of cultivators, the mutable character of the Seerusteh Butta, which necessarily changes with the yearly varying total assessments of the village, and which Seerusteh Butta is not determinable until all other assessments be fixed, combine great evils, and, unless to the most practised, patient, and persevering investigator, present an inextricable mass of confusion. The evils

are, that a cultivator, be he lettered or not, cannot by possibility know what he will have to pay the ensuing or even the present year, because fixed sums, payable by the village, are divisible amongst a varying number of cultivators. Even if fixed sums were divisible amongst a fixed number of cultivators, the limited progress in arithmetic of the poor people would utterly disable them from determining their respective fractional shares; for instance, of 4 rupees for skins and shoes, 1 rupee for beit,[a] $4\frac{3}{4}$ for ghee, and $1\frac{5}{16}$ for leaf plates, &c. &c. In the whole course of my personal inquiries amongst this class for more than six years, I never met with one Koonbee who could or would give me a detail of his assessments or their amount; the constant reply was, "The Koolkurnee knows." This very uncertainty of their means and liabilities makes men improvident and careless.

The next evil is, that the Koolkurnee, in apportioning the fixed sums, and the Seerusteh Butta, the commutation money for grain, for ghee, sugar, pumpkins, &c. &c. is assured of impunity in defrauding the cultivators, from their want of hability in their accounts, even if they were aware of the value and amount of the cesses and the number of persons they were to bear upon. It is almost waste of labour to give the cultivator a note from government of what he will have to pay, as in nine instances out of ten he cannot read it; his expounder is the Koolkurnee, or the Koolkurnee's relations, and they read it agreeably to their own calculations.

The above is an exposition of the assessments as they now bear on the land, which produces 82·30 per cent. of the whole revenue. The remaining portions of the revenue, which appear in village papers are usually classed under the term Sahyer, and are in fact taxes. The two principal heads of Sahyer are Mohturfa, properly "Arhan," or taxes on shops, houses, and professions; and Bullooteh.

Operation of Sahyer Taxes.—An idea of the operation of these taxes will be formed by the following details from Wangee, Pergunnah Wangee.

Wanees, or sellers of grain and groceries, from 4 to 6 rupees a shop; oilman, for one oil-mill in work	6 rupees.
Weavers, per loom	3 do.

Other tradesmen pay proportional taxes. The threshold tax is called Oombraputtee, from Oombra, threshold: it is generally a rupee per house.

At Tellegaon, Pergunnah Paubul, Poona collectorate, the

[a] Beit, "a present."

taxes on trades are fixed on a scale of annas relatively to the visible means and profits of the tradespeople. The anna is considered equivalent to $3\frac{1}{2}$ rupees. The trades are taxed from $\frac{1}{4}$th anna to 2 annas, or 7 rupees, which is the highest sum for one shop.

The highest tax on one weaver is half an anna, or $1\frac{3}{4}$ rupee; oilman, highest rate one anna, or $3\frac{1}{2}$ rupees; the saddler, dyer, and butcher, at half an anna each, or $1\frac{3}{4}$ rupee; fishermen, dealers in sweet potatoes, and makers of bridles, 1 rupee each; the *community* of braziers, 10 rupees. All the Momeens who are Moosulmans and weavers of turbands taxed in the lump at 25 rupees; shepherds at 14 rupees. These taxes are not raised on any systematic principles of application.

Bullooteh Tax.—The Bullooteh is a tax levied on the persons called the Bara Bullooteh, or artizans and functionaries twelve in number, who are important personages in the village constitution.

The taxes on the Bullooteh are generally deemed to be on the exercise of their profession; but this is a mistake, as the astrologer and Guruw, or sweeper of the village temple, pay Bullooteh tax, although not artizans; and I have known individuals of a trade (in one instance a boy the survivor of a family) paying from 20 to 25 rupees per annum, which they could not possibly do from the gain of their handicrafts.

The fact is, the Bara Bullooteeh have annual grain fees from the cultivators; and government, in former times, deeming these fees more than commensurate with the value of the labours performed, took a part of them in money. The taxes on the Bullootehdar, are therefore indirectly derived from the land; some of these taxes fall very heavily. At Wangee three carpenters pay 36 rupees Bullooteh tax, Wurgut 9 rupees, and house tax 3 rupees for three houses. At Tellegaon, Turruff, Paubul, the Bullooteh taxes are yet higher: carpenter 50 rupees, shoemakers 60 rupees, Guruw or sweeper of the temple 30 rupees, barber 24 rupees, washerman 8 rupees, Moolana, or Moosulman priest, who also gets Bullooteh, 8 rupees; but the cultivators are numerous, and the lands of Tellegaon under cultivation extensive. The Bullootehdar on the whole therefore reaps a rich harvest, in spite of government participating in his fees, from the cultivators. It is unnecessary to multiply instances of the bearing of the Sahyer taxes. Taxes for the sale of spirituous liquors, and the amount of customs or transit duties, rarely appear in village papers, as those branches of the revenue are mostly farmed.

My limits do not permit me to give a detailed statement of the manner in which village accounts are kept under a native

government. It would much assist to illustrate the internal œconomy of a village and many local usages, but I have not space. I can only say that the whole accounts of a village are kept on a ribbon of paper, about five inches wide and some yards long, not rolled up but folded in lengths of twelve inches or more: one of these is required for each year. At Wangee it is called *Gao Jarah*, or village search; at Kurmulla *Jhartee Akaar*, or figures or signs of search; at Barlonee it has the compound term of *Lownee Putruck*, (detail of cultivation,) and *Zumeen Jarha*, (land search); at Rawgaon it is called *Wussool Jarha*, or search of collections: occasionally it is *Akaarbund*, or roll of signs, items, figures. These varying names result from the union of two papers which are usually kept separate; namely the *Thul Jarha*, or roll of lands by family estates; and the *Lownee Putruck*, or roll of cultivation and assessments.

In closing the notice of assessments, a few words are necessary to explain the method of keeping village accounts. At the head of the paper called *Gao Jarha* is the name of the village, the Pergunnah and Soobeh it is in, the year and the name of the government it is under; this is followed by the Tunkha or Moghul money assignment upon the village, the Moosulmans having fixed each village to pay a definite sum, leaving the whole details of assessment and distribution to the Pateel and villagers; then follows the total quantity of land belonging to the village: deductions are made for land in boundary disputes, for Eenams of all kinds, whether to the temples, to the village officers, to the Deshmook or Deshpandeh, or to individuals, the quantity to each being carefully marked; all these being deducted, the remainder is distinguished into garden and field-land; then follows a roll of the cultivators, with a number of columns to record the quantity of land held upon each tenure, and the amount payable for each; a column for the share of the extra assessments, previously noticed, including the share of village expenses, which is always considerable; also columns for totals of the different heads. Then follow rolls of the Bullooteh, shopkeepers, trades, and others subject to fixed taxes, with columns for the proportion of tax upon the particular trade; the Bullooteh, the house-tax, and share of extra assessments, which these people pay although they are not landholders.

An abstract of the preceding details is now made, called the *Ekunder Tereej*. The contract for the transit duties, if not farmed, is added; and the *Kumall*, which means "total," "all," "whole," is put at the bottom. Then follow the deductions under the heads of money—Eenams, Hukdars, village, and other expenses, every item of which is detailed. Amongst the expenses

are village festivals, dinners to government officers, donations to brahmans, feeding pilgrims, interest on money borrowed, expenses of the Pateel and village officers when attending the governor of the district, oil in the temples, the Moosulman saint's tomb (if there be one) coming in for its share of donation or annual allowance, strange as it may appear, from Hindoo cultivators. I regret much that my limits do not permit me to detail the expenses, many of which are very curious, and illustrate habits and customs. The expenses being deducted from the collections, a balance is struck, which, under native governments, *left* the Tunkha, or government original assignment, together with any extra assessment, if levied, such as Sur Deshmookee, Chouth, &c. &c. To show how large a proportion of the village collections did not go to government, in one village, whose accounts I translated, the Tunkha, or government share, was 5500 rupees; and the Kumall, or total collections, 8522 rupees; so that 3022 rupees, or more than 35 per cent. of the whole, went in village expenses, Hukdars, (Deshmooks and Deshpandehs,) and other claims.

Wages.

The amount of wages of agricultural labourers is of so much importance to the class constituting the major part of the community, and it assists the judgement so materially in estimating the condition of the people, that I shall offer all the details I was able to collect in the Dukhun bearing on the question.

Farmers' Artificers' Work executed for Fees in Kind.—The trifling artificers' and mechanics' work required by the farmer being performed by the village artisans, in virtue of their offices and for fees in kind, it will not be necessary to enlarge on the remuneration for their labour: but to afford distinct ideas of its value, at the end of this paper I shall put into juxtaposition the rates paid by the Peshwah's government and the British government to artificers, mechanics, and others.

I made my inquiries on the subject of wages in towns and villages, the most distant from each other, to prevent the mistake of the adoption of local rates for those of general operation.

Wages of Husbandmen and other Labourers at Nandoor.—At Nandoor, a British town in the Ahmednuggur collectorate, in March, 1827, I found that yearly husbandry servants got from 12 to 20 rupees[a] per annum and their food; a smart active man got about 15 rupees per annum and supplied himself with clothes.

[a] From 24 to 40 shillings.

Day labourers, when paid in cash, get $1\frac{1}{2}$ anna per day, or $\frac{3}{32}$ of two shillings, (about two pence farthing,) supplying themselves with every thing: but day labourers are never paid in money unless when grain is very dear.

Quantity given. — The most usual plan in harvesting crops is to give each labourer three sheaves of whatever grain he is cutting down; and provided he ties up the sheaves and stacks them, he gets five sheaves a day.

Value of Wages in Kind, converted into Money.—The grain in five sheaves, in ordinary seasons, amounts to about two seers. At the price of Bajree*, in March 1827, at Nandoor, namely 42 seers per rupee, the value of the labour was one penny and $\frac{14}{100}$ths per day. Joaree†, at 56 seers per rupee, was $\frac{85}{100}$ths of a penny per day, or rather more than three farthings. Wheat, at 18 seers per rupee, would have been two pence $\frac{66}{100}$, or something less than two pence three farthings per day. Allowing the grain in five bundles to be double the quantity stated, which is rather possible than probable, the highest wages in harvesting wheat would not have been five pence halfpenny per diem. When men are employed in ploughing or harrowing, nine times out of ten, they are paid two seers of Bajree for their day's work, from daylight to night, allowing one hour for dinner.

At Kanoor.—At Kanoor, a town in Jagheer, Ahmednuggur collectorate, in March 1827, I found that the two Pateels had each a permanent domestic servant in his employ; one paid his man 15 rupees per annum and his food; the other gave 15 rupees per annum, food, and five articles of wearing apparel, the value of which was $3\frac{1}{2}$ rupees.

Wages at Dywuree.—At Dywuree, Nuggur collectorate, in November 1826, the cultivators did not pay their day-labourers in money, but gave them five sheaves of grain for every hundred cut down; a very able man indeed might cut down two hundred sheaves in a day, which would give him four seers of grain, the value of which (Bajree) in November, 1826, was about $\frac{2}{16}$ths of a rupee, or three pence English.

Wages at Dytna.—At Dytna, Nuggur collectorate, in February 1827, I found a man getting 25 rupees per annum, his food and a blanket, his son being also in employ at six rupees a year, food and clothes; but this was looked upon as high, and the individuals getting such wages fortunate: the village belonged to a Gosawee ‡ who paid his people well.

Wages of Women Day Labourers. — At Chambergoondeh, a large town belonging to Seendeh, Nuggur collectorate, in

* Properly, Sujgooreh, *Panicum spicatum.*

† Properly, Jondleh, *Andropogon Sorghum.*

‡ Gosawee, *a religieux.*

November 1827, women weeding in fields got $\frac{1}{16}$th of a rupee per day, or one penny halfpenny, and worked from sunrise to sunset.

Wages at Kurkumb.—At Kurkumb, a Jagheer town in the Poona collectorate, in December 1827, I found a husbandry servant getting only twelve rupees per annum, and food twice a day: no clothes. A man watching a field of grain was a monthly servant at three rupees a month, without food or clothes.

Highest Wages at Kurkumb.—From the authorities of the town I learned that the highest rate paid for the cleverest gardener's assistant or ploughman was 25 rupees per annum and daily food, but without clothes. The monthly rates for agricultural servants were from $2\frac{3}{4}$ to 3 rupees, without food, or clothes, fee, or advantage.

Pay of Seypoys at Angur.—At Angur, a British town in the Poona Collectorate, on the 9th of January, 1828, in looking over the village accounts, I found two village seypoys charged respectively three rupees and two rupees for a month's pay.

Wages of Women Labourers at Poona.—On the 21st July, 1827, I found a great number of women weeding in gardens in the neighbourhood of the city of Poona; they received each six pice in money, or $\frac{6}{61}$ths of two shillings, (two pence one-third per day,) and worked from daylight until dark. This may be considered high wages, and its amount is to be attributed to the paucity of field labourers in a great city.

Wages at Pait.—At Pait, a Jagheer town in Pergunnah Kheir, in the Poona collectorate, on the 16th February, 1829, in my evening excursion, I overtook twelve or fourteen men and women with bundles of wheat in the straw on their heads; on inquiry I found they had been employed as labourers in *pulling up* a field of wheat at Pait. Their wages had been five sheaves for every hundred gathered; two or three of the men only had got five sheaves each, the majority of them only four, and the women none more than three. Five sheaves they said would yield about four seers of wheat, and as wheat was selling in Pait at 28 seers per rupee, each man with five sheaves received for his labour nine pice, or $3\frac{1}{2}d.$ English. These poor people belonged to the town of Owsuree, five miles distant from Pait; they had therefore a march of ten miles to make besides their day's labour.

Wages at Joonur.—At the city of Joonur, at the end of February 1829, I found a brahman cultivating the Hubbus Baugh (about 80 beegahs of land); he employed numerous labourers. While I was encamped near his garden, fields of wheat, and gram, and Booee Moong*, &c. were harvested. For the

* Earth-nut, *Arachis hypogea.*

wheat and gram and bread-grains the men got five sheaves per cent. In the field of Booee Moong there were between fifty and sixty women employed; and I learned that, in this particular product, from the labour and tediousness of digging it up, and the cheapness of the produce, the labourers were allowed one-fourth of the whole. In cutting down sugar-cane, gathering fruits or vegetables, and indeed where the produce was too valuable to give the labourer a share of it, the Brahman paid a man eight pice a day (little more than $2\frac{1}{2}d.$) and a woman four, and they worked from daylight until dark, with an allowance of one hour for dinner.

The above data are gathered from places widely separated in the Poona and Ahmednuggur collectorates; and although in different years, are remarkable in their uniformity; they supply therefore just estimates for the general rates of wages, and it may be fairly stated that the highest money wages paid by the natives to any husbandry or domestic servant is four rupees per month, with which he finds his own food and clothes, and $2\frac{1}{12}$ rupees per month is the pay when the master supplies food and clothes; and the most favourable wages to a man day-labourer are eight pice per diem *, and to a woman five pice †.

Artificers' and servants' wages, and price of Bread-grains under the Peshwa's and British Governments.

Rates of hire for a month of thirty days of artificers, servants, and labourers in Dukhun, under the British government in 1828, and Peshwa's government in A.D. 1814.			Prices of grains, pulses, and other articles, the ordinary consumption of artificers, servants, labourers, &c. at Poona in Dukhun, under the Peshwa's government, being a mean of five years from 1811 to 1815, and under the British in 1828.		
Denomination of artificers, servants, &c.	Monthly Pay. Under the British.	Monthly Pay. Under the Peshwa.	Grains, pulses, and other articles.	Seers per Rupee. Under the British, 1828.	Seers per Rupee. Under the Peshwa, 1814.
	Rupees.	Rupees.		Seers.	Seers.
Maistry, or head carpenter	25, 35, 40	15	Rice, Putnee	16	12
			Do. Ambemor ...	13	$9\frac{1}{2}$
Second or under do.	23 & 25	12	Do. Rajawul......	14	12
Maistry, or head carpenter, finest worker	30, 35, & 45	15, 20, 40	Wheat, Buckshee	18	$14\frac{1}{2}\frac{4}{4}$
			Do. Potee	20	...
			Joaree (*Andropogon Sorghum*)	32	$21\frac{1}{3}$

* About $2\frac{3}{4}$d. † About $1\frac{3}{4}$d.

Table continued.

Denominations of artificers, servants, &c.	Monthly Pay. Under the British.	Monthly Pay. Under the Peshwa.	Grains, pulses, and other articles.	Seers per Rupee. Under the British, 1828.	Seers per Rupee. Under the Peshwa, 1814.
	Rupees.	Rupees.		Seers.	Seers.
Carpenter, common worker ...	15 & $22\frac{1}{2}$	12	Bajree (*Panicum spicatum*)	28	$17\frac{62}{200}$
Two Sawyers	15 & 22	8	Dhall (*Cytisus cajan*)	16	$11\frac{86}{100}$
Maistry, or head smith	25 & 30	20	Ghee (clarified butter)	2	$1\frac{1}{2}$ to $1\frac{3}{4}$
Smith	15 & $22\frac{1}{2}$	12			
Head armourer ...	30	20			
Armourer	15	12			
Fileman	15	12			
Hammerman	6, 8, & $13\frac{1}{2}$	$7\frac{1}{2}$			
Maistry, or head leather worker	15	12			
Leather worker, harness maker	$9\frac{3}{4}$	9			
Puckalee, or waterman	15	9			
Bricklayer	$9\frac{3}{4}$, 12	10			
Head bricklayer, maistry	25 & 35	15 & 20			
Maistry, or head tailor, fine worker	15	14			
Tailor	$9\frac{3}{4}$	6			
Man labourer	5 & 7	5			
Woman do.	$3\frac{3}{4}$ to 7	3 to 4			
Boy do.	$3\frac{3}{4}$	3			
Muccadum, or chief of Dooly bearers	15 & 20	8			
Dooly bearers	7 to 9	6			
Horse keepers......	8	5	Served two horses	under Peshwa.	
Camel men	7 to 9	5	Served two camels	Do.	
Tattoo, or pack pony per month, with driver ...	12	15			
Camel with driver.	30	30			
Puturwut, stonemason	...	12			
Bhooee Hamalls...	7, 8, & 9	6, 7, & 8			
Muccadum, or chief of Hamalls	15	10			

The above table shows a marked enhancement in the wages of all classes of handicrafts and servants, although grain became from 20 to 50 per cent. cheaper under the British than

under the Peshwa. In the wages of the numerous servants of European gentlemen the same advance has taken place. The superior cheapness in some grains has extended to more than 100 per cent.

In the above notices the rupee has been considered equal to two shillings; the seer of weight equal to 1 lb. 15 oz. 8 drs. $18\frac{3}{4}$ grs. avoirdupois, or 2 lbs. 4 oz. 6 grs. troy; and the seer of capacity to 2lbs. 6 oz. 3 drs. 24 grs. 92 dec. avoirdupois of Jerwail rice; its cubic contents, 72 in. 2 dec. of water at a temperature of 75° Fahrenheit, at a temperature of 60° therefore being equal to 48 per cent. less than two imperial quarts, or very nearly one quart. Rigidly, the seer is 4·17 dec. per cent. larger than an imperial quart.

Manufactures.

Celebrated as was India for its costly and ingenious cotton fabrics, little more than the memory of them now remains. The machinery of England has enabled her manufacturers to take the raw material out of the hands of the grower, and return it to the continent of India, worked up in various ways, without even affording an opportunity for the application of a prop or stay to the sinking industry of its once flourishing manufacturing classes. As far as relates to Dukhun, its cotton and silk fabrics are confined to coarse dresses for women, tent-cloths, some silk handkerchiefs, and trifling pieces of silk for bosom cloths for women. From an examination of the cotton and silk goods for sale in the markets of Poona, in July 1829, it appeared that every product of the loom, without any exception, with any claim to notice from texture, costliness of material, or ingenuity in the design or workmanship, was an import into the collectorates from native states not under the British government. Turband cloths, varying in length from 24 to 60 cubits, in breadth from three-quarters to $1\frac{1}{2}$ cubits, and in price from one rupee up to sixty rupees each, were from Peytun, Bheer, Narrainpait, Tahr Putruh, Wuswunt, Nandergaon, and Shaghur, in the Nizam's dominions; Boorhanpoor and Jehanabad, in Seendeh's (Scindiah's) dominions, and Chundaree in Malwa, while those made in the city of Poona did not exceed three rupees each in value. The only valuable *Dotruhs* or loin cloths, in length from 20 to 22 cubits, breadth $2\frac{1}{2}$ to $2\frac{3}{4}$ cubits, and in price from 10 to 40 rupees, were from Muheshwur, in Malwa; the rest were from the Nizam's, Holkar's, and the Rajah of Berar's (Nagpoor) territories. Shahpoor and Belgaon, in the Dharwar collectorate, produced some loin cloths of the value of 25 rupees; those from

Poona did not exceed three rupees in value. The *Dooputtehs* or *Shelehs*, cloths for throwing over the shoulder and enfolding the body, in value from 10 to 200 rupees, were from Peytun, Jehanabad, and Boorhanpoor; those from Poona were of the value of five rupees only. Loogreh or Sarhehs*, varying in length from 13 to 20 cubits, in breadth from $1\frac{3}{4}$ to $2\frac{3}{4}$ cubits, and in price from $1\frac{1}{2}$ rupee to 80 rupees, had a wider field of production, even Poona producing these dresses, from one or two looms only I believe, of the value of 80 rupees. New Hooblee, and Shahpoor, in the Dharwar collectorate, produced some dresses of the value of 30 rupees. *Cholkun* or bosom cloths are manufactured at the above places: the highest value of one would appear to be 10 rupees, and the lowest about threepence. The silk handkerchiefs were chiefly from the Carnatic.

The price of the above articles is influenced partly by the colours, partly by the fineness of the fabric, but chiefly by the quantity of gold and silver thread worked up in them.

Some cotton carpets are manufactured at Ahmednuggur, and in the Jail at Poona, but do not call for notice.

Turbands are dyed of twenty-one colours, but I have not space to give the names; few or none of them are fast colours, with the exception of black and red.

The only woollen manufacture in the collectorates is that of a black smooth blanket, (*Kumlee*) the colour being that of the wool. In general the blanket is coarse, but there is a very fine fabric from Bijapoor. The low state of manufactures is otherwise attested by the fact that, in the Poona collectorate, in the population returns sent to me, the weavers only amounted to 0·35 per cent. of the people, or one weaver for every 280 souls; in Khandesh 0·57 per cent., or one to every 173 inhabitants; and in Dharwar 1·80 per cent., or one in 55 inhabitants, which is prodigiously above the other collectorates. I *estimate* the proportion in the Ahmednuggur collectorate to be the same as that in Poona.

Transit Duties.

The transit duties are farmed; the stations for collecting them are numerous; the rates, although fixed, are unjust, as they are not levied on uniform principles with respect to definite tracts of country. The Carrier is not only interrupted at irregular intervals by British stations, but the alienated towns, so numerously interspersed in the British territories,

* Women's dresses.

endeavour to levy duties; moreover, he is perplexed by the money claims of hereditary district officers upon the duties, independently of the customs-farmer's dues. How the conflicting interests are arranged I do not know; but they are so various and troublesome, that the merchant is commonly driven to the expensive necessity of contracting with a class of people, called *Hoondeekuree*, who undertake for a *fixed sum* to pass all the merchandize through a country to its destination, paying all duties; constant practice, adroitness, and bullying, enabling them to arrange with the collectors better than the merchant could.

All transit duties should be abolished; their amount in the interior of a country materially affects consumption, and is therefore injurious to trade.

Coins.

The only coins in use in Dukhun are silver rupees, half rupees, and copper pice. The rupees are of many mints, and have a different value in relation to the copper coin, resulting from the age of the rupee, and the number of punches or marks it may have on it made by the Shroofs or money-changers in passing through their hands *; the same rupee, of the same standard, and same mint, has not the same value *in copper* in neighbouring districts; this value fluctuates at the pleasure of the money-changers. On what principles they regulate the relative values I do not know. The multiplicity of coins of different mints, and the gradations of coins of the same mint, are great evils. It is unnecessary to enumerate these coins, as they are in the Bombay Almanac.

Weights and Measures.

A very considerable diversity prevails in every district, and often in neighbouring villages, in the weights and measures in use, whether of weight, length, or capacity; this diversity goes so far, that the subdivisions are often found not to be in a determinate proportion to each other. All this confusion is referrible to the want of an ancient permanent standard; to the abrasion or decay of the weights and measures tolerated by government, the knavery of the owners of the weights, and the apathy or connivance of the district authorities †. Everywhere

* These marks occasion a depreciation of one or more per cent.

† So great are the discrepancies, that they range from 41 per cent. below to 100 per cent. above the Poona standard.

the apparatus of metrology is characterized by clumsiness in construction; rough stones are commonly substituted for stamped metal weights, and joints of the hollow bamboo for authorized definite measures of capacity. The seer of weight was directed by the authorities at Poona and Ahmednuggur to be of eighty Ankoosee rupees, and such a weight may be in use where the district officers are located, but in very few other places. With respect to measures of capacity, not only has each village its own, but I might almost say that each shopkeeper has his own, for it is rare that the weights and measures of any two shopkeepers are identical; and when it does occur it must be referred to accident. Even the stamping of weights and measures by government officers has not been effectual to insure uniformity; for in a table that I drew up of the discrepancy between the weights and measures of some scores of places all over the country, very many of the weights and measures had the government stamp upon them.

One feature of the measures of capacity is, that, with some exceptions, those of villages are always larger than those of towns and cities. The extent to which this fraud has been carried in military cantonments and large bazaars immediately under British control, is shown in the fact of the reduction of the Serroor cantonment seer, one-twentieth below the standard of Poona city, one-fourth below the standard of Ahmednuggur city, and two-elevenths below the measures of neighbouring districts. But in Bombay it is still more glaring, the origin of whose weights and measures is unquestionably referrible to the Dukhun and Konkun; and yet the Bombay measure of capacity is 41 per cent. less than that of Poona, and about 33 per cent. less than that at Panwell in the Konkun, the nearest great mart to Bombay on the continent. The diminution in the seer of weight in Bombay is even more striking. I found the standard seer of weight in the collector's office in Bombay to weigh 4970 grains troy only, while the Panwell seer weighed 13,110 grains, and the Poona seer weighed 13,800 grains, troy. The Panwell seer therefore was 163 per cent. and the Poona seer 177 per cent. larger than the Bombay seer. The knowledge of these facts is of importance to the European and native merchant, as well as to the general consumer.

The evil of a progressive diminution in the weights and measures of Dukhun is arrested in the cities of Poona and Ahmednuggur and the neighbouring cantonments, by standards being kept in the collectors' offices; but as they are not founded on any scientific principles by which they could be restored if lost or *lessened,* their safe custody is of great moment. The seer

of weight is directed to be made of a certain number of pieces of the current silver coin, and can therefore be tested without difficulty; but there is not any test, saving the solitary standard in the collector's office, for the measure of capacity. It will be seen that I have given the weight of water of a certain temperature these measures contain, and this determination may be of use at a future period.

Grain measures.—The largest measure of capacity in use is the *Adholee*, of two seers; its name means "the half," it being the half of the *Puheelee*, of four seers, which is not in use. This measure is in the form of an hour-glass. I found the *Poona city* standard to contain 36,400 grains troy, of water, at a temperature of 75° Fahr., or 5 lbs. 3 oz. 3 dr. 5½ grs., or 144·4 cubic inches; and at a temperature of 60° Fahr. it contained 36,462 grains troy, being 48 per cent. less than an imperial gallon, or very nearly two quarts; rigidly, the seer is 4·17 per cent. larger than an imperial quart. It is curious that the first subdivision of the *Adholee* is not one-half but one-fourth, or half a seer, a seer measure being very rarely in use; then a quarter of a seer, and finally, one-eighth.* In some places there are what are called male and female *Adholees*, one being a little larger than the other; retail traders buy with the largest and sell by the smallest. The multiples are 2 *Adholees* 1 *Puheelee* or 4 seers, 12 *Puheelees* 1 *Mun* (Maund), and 20 *Muns* 1 *Kundee* (Candy); but in some places there are 16 *Puheelees* to the *Mun*: and along the Ghàts, and in the Konkun, there are only 3½ seers to the *Puheelee*. Determined by the weight of the contents of the *Adholee* of well-dried Jerwail rice, the *Kundee* would be 20 cwt. 1 qr. 26 lbs. 10 oz. 12 drs. 16 grs. avoirdupois.

It is necessary to mention that the *flour* of *all grains* is sold by weight and not by measure.

Oil, spirits, and milk, are sold by different measures of capacity. These are all professedly founded on the seer of weight; but their discrepancies may well render it doubtful. At one place I found the seer of oil measure to contain 26 rupees' weight of water, at others, 66 rupees', 80 rupees', &c. The forms of these measures are various. The same observations apply to spirit measures. The seer of milk in one place contained 88 rupees' weight of water, in another 93, and elsewhere up to 109 rupees' weight.

Weights.—The standard seer of weight in Poona weighs 80 Ankoosee rupees or 13,800 grains troy, or 1 lb. 15 oz. 8 dwts.

* Sellers of sweetmeats have $\frac{1}{16}$th of a seer.

$18\frac{3}{4}$ grs. avoirdupois; but the most common seer in use in Dukhun is one of 76 rupees; the divisions are *Adh seer* (half), *Pao seer* (quarter), *Adh pao* or *Nowtank* (one-eighth), and *Chettank* (one-sixteenth). For the convenience of calculation, the seer is divided into 72 *tanks* or *tollahs,* and one-eighth, of course, is *Nowtank* or nine tanks, and one-sixteenth is *Sarhee chartank* or $4\frac{1}{2}$ tanks, which is corrupted into *Chettank.* The multiples are *Panch seer* (five seers), the *mun* of 40 seers equal to 78 lbs. 13 oz. 11 drs. 11 grs. avoirdupois, or 95lb. 10 oz. troy exactly; the *Pullah* of 3 *muns,* and the *Kundee* of 20 *muns.* But I have shown how far the weights really in use differed from the above, and in the tract lying between the Seena and Beema rivers, the weight called the *Bureedee* had not even the same constituents or multiples as the Poona weights.

Goldsmiths' weights.—The lowest goldsmiths' weight is nominally the mustard seed, but the lowest I met with was the *Goonj,* a seed of the *Abrus precatorius,* the mean weight of which was 1·91410 grains troy: 96 *goonj* make a *tollah,* which should therefore weigh 183·7536 grains troy; but as the *tollah* is the 72nd part of a seer of 13,800 grains, it should weigh 191,666 grains troy; the goldsmiths' weights in use consequently are below the nominal standard. Eight *goonj* or four *waals** make one *massah,* and twelve *massah* one *tollah.* I put the goldsmiths' weights to the same test in different parts of the country, I did those of capacity, and found that two weights of the same denomination in different shops were seldom uniform. The scales used by goldsmiths are called *Kantah,* and are of metal; those used by dealers generally are called *Tajwa* or *Tagree,* and are made of leather or parchment.

Itinerary and Long Measures.—Distances between places are *estimated* by the *Kohs* (coss), I cannot say *measured,* for I believe the actual determination of distances between places was as little attended to by the native governments, as the facilitating communications through the country by the construction of roads and bridges. I *think* the *Kohs* averages about two miles English, varying, however, from $1\frac{1}{2}$ to $2\frac{1}{2}$ miles. In Mahratta writings long measure is raised from the barleycorn; 8 *Juw* or barleycorns make a *Boht* or finger, 24 fingers a *Haht* or cubit, (18 inches), 4 cubits a *Dunoosh* (a bow) or fathom, measured by a man's outspread arms, and 8000 cubits or 2000 fathoms a *Kohs.* The *Kohs* therefore would equal $2\frac{1}{4}$ English miles and 40 yards. In Sanscrit 2 *Kohs* make a *Guwyotee,* and 2 of the latter make a *Yojun* or 9 miles and 160 yards; but these terms

* Waal is the seed of the Cæsalpinia sappan.

are unknown to the common people. In fact, however, the measure of length originates in the well-known *Haht* or cubit, determined by the *mean length* of five men's arms, measured from the elbow-joint to the end of the middle finger: the *Haht* or cubit so determined, is a little more than 18 inches in length; this is divided into 2 *Weets* or spans, into 6 *Mooshtees* or fists, and each fist into 4 *Bohts* or fingers, and the latter into 8 barleycorns each. Tailors and sellers of cloth use a *Guj*, which is divided into 16 *Ghirra*, each of $1\frac{1}{3}$ *Tussoo*, each *Tussoo* of 2 *Bohts*, and as each *Boht* is equal to a fraction more than $\frac{3}{4}$ of an inch, the *Guj* would be a little more than an English yard.

Superficial Measure.—The only land measure of any exact and appreciable extent is the Beegah, which is of Moosulman derivation, but by some referred to the Sanscrit word *Weegruhuh*, although this word is not applied to land measurements; and as all genuine Mahratta terms applied to the capacity, extent, or capabilities of land, are not referrible to the beegah or its multiples, I must consider the Beegah of Moosulman introduction. Like itinerary measures, it is raised from the *Haht* or cubit of a fraction more than 18 inches in length; 5 *Hahts* and 5 *Mooshtees* (fists or palms) make 1 *Kattee* or stick, 20 square *Kattees* or sticks make 1 *Paand*, and 20 *Paands* a *Beegah*; reduced to English measurements, the 5 *Hahts* and 5 *Mooshtees* will be equal to 105 inches in length, and the square of this sum will be 11,025 inches in a square *Kattee* or stick, and 20 *Kattees* a *Paand* equal to 220,500 inches, and 20 *Paands* a Beegah or 4,410,000 square inches; and as the English statute acre contains 43,560 square feet, the Beegah is to the acre as $70\frac{1}{3}$ is to 100, or as 211 to 300, being a trifle more than seven-tenths of an acre. But as the *Haht* or cubit is a fraction more than 18 inches, the Beegah may fairly be considered equal to three-fourths of an acre: but I very much doubt whether any other than garden lands were actually measured by the Moosulmans; and in converting the Hindoo terms *Kundee, Mun, Doree*, and fifty other denominations, into Beegahs, it was done by *estimate*; and this explanation will account for the variable size of the Beegah in different parts of the country, which the British survey has discovered. The only multiples of the Beegah, to my knowledge, are the *Rookeh* of 6 Beegahs or $4\frac{1}{2}$ acres, and the *Chahoor* of 120 Beegahs or 90 acres: these terms are of Moosulman origin.

Adverting to the past and present state of the knowledge of native governments in politics, political economy and science,

it would be idle to refer the origin of their weights and measures to scientific principles, immutable standards, or even to any uniform, although arbitrary system. Their long measure is derived from the human arm, and their weights from a seed. In these derivations they have not been a whit more irrational than the good people of England, whose standard measure of length, the *Ulna* or *Ell*, is derived from the arm of one of their kings, (Henry the First), and their weights from grains of wheat. There is a great coincidence between the native weights and measures and those of antiquity. The first five subdivisions of the scripture measures of length are identical in their derivation, and nearly so in their length, with those of Dukhun; namely, the finger, fist or palm, span, *Haht* or cubit, and fathom; both also have the coincidence of being destitute of a measure equivalent to a foot. The foot was a constituent of the ancient Greek and Roman measures; but in *practice* these nations used the finger, palm, and cubit; and the *Pecus* or great cubit of the Greeks was precisely of the length of the Dukhun cubit, namely, a fraction more than 18 inches. The ancient grain and liquid measures of England were raised from weight from a pound troy. For a very long period I had believed the measures of capacity in Dukhun to be entirely arbitrary; but in the southern part of the country between the Seena and the Beema rivers, I met with *Adholees* with *stamps* on them, directing that they should contain a *certain weight* of grain; for instance, at Punderpoor the *Adholee* was to contain as much *Johr Guhoon* (wheat), as would weigh 200 Ankoosee rupees, at Mohol 160 rupees' weight of Joaree (*Andropogon Sorghum*), at Taimbournee 131 rupees' weight of Joaree, and at Kothool, near to Ahmednuggur, 200 Ankoosee rupees' weight of Bajree (*Panicum spicatum*). I know not whether this slight indication of systematic deduction of measures of capacity from those of weight is attributable to the Moosulmans or to the Hindoos. The places where they were met with, with one exception, had until recently, been for ages under a Moosulman government (the Nizam's), but it might have been practised before the arrival of the Moosulmans. It does not appear to have occurred to the natives to use the weight of water, as the least changeable standard by which to fix the capacity of a measure.

Army.—The army consists of some of the royal troops paid by the India Company; of European regiments of artillery and infantry belonging to the Company, and of native regiments of cavalry, infantry, and pioneers, armed, clothed and disciplined in the same manner as the European troops. The army is

separated into divisions commanded by General Officers and Brigadiers-General, and the divisions are divided into brigades, which are so stationed as to co-operate in the readiest and most efficient manner in emergencies, for the protection of the country and the maintenance of the civil power.

Justice.—Not having been able to get blank forms filled up at the India-House with the necessary data respecting crimes and punishments, I abstain from any notice of judicial matters.

W. H. SYKES, Lt.-Colonel, F.R.S.,
Late Statistical Reporter to the Government of Bombay.

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On the relative Strength and other mechanical Properties of Cast Iron obtained by Hot and Cold Blast. By Eaton Hodgkinson, *Esq.*

[With a Plate.]

From the great abundance of the ores which produce iron; from the fortunate circumstance of these ores being frequently found in the neighbourhood of coal and limestone, by which they are reduced to the metallic state; from the great strength of the metal, and the facility with which it can be moulded into any form required—its uses in the arts have become very extensive. Every discovery, therefore, tending to facilitate its production, or to improve its quality, must always be regarded with great interest, whilst distrust and suspicion are likely to be felt respecting any process by which that quality may be supposed to be impaired.

The recent and very general introduction of a heated blast into the smelting furnaces has consequently, as might be expected, given rise to much discussion, and at the same time to great difference of opinion. Iron masters in one part of the country had come to a conclusion that the new process greatly deteriorated the quality of the iron produced, and they rejected it accordingly. Gentlemen from other neighbourhoods, on the contrary, maintained that no deterioration of the metal resulted from the process, which was admitted by all to diminish the expense of its production.

These very different conclusions, drawn by persons largely connected with the manufacture of cast iron, caused the honour of an application from the British Association for the Advancement of Science, at its meeting held at Dublin, to my friend Mr. Fairbairn and myself, requesting us to make a series of experiments tending toward the determination of this matter.

We intended to commence the inquiry immediately, but there was found to be great difficulty in obtaining irons suitable for the purpose; a matter which will be adverted to in Mr. Fairbairn's report, where a description of the irons used will be given.

In the prosecution of this research it was conceived desirable to subject the metals operated upon to more than one species of strain, in order to elicit their peculiar properties; and accordingly they were generally broken in the following three modes:—

1st. By tension, or tearing the metals asunder in the direction of their length.

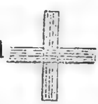
2nd. By compression, or crushing specimens of different lengths, and various forms and sizes of base.

3rd. By a transverse strain, and this under different forms of section.

In this last mode of fracture some bars have been broken under various temperatures, and others have been loaded for a very long time with weights, nearly as large as would have broken them at once, and they are still bearing the loads.

The experiments on the transverse strain (excepting those on the Carron iron, No. 2, the Devon, and the Buffery, of which I read an account at Bristol) were made by Mr. Fairbairn, who undertook also the experiments on the effects of temperature and time. I was desirous that he should try the effect of time upon loaded bars, being convinced that it would do little or nothing to destroy their power of bearing a dead weight; having arrived at this conclusion from experiments made in a different way upon malleable iron. As I was present at many of Mr. Fairbairn's experiments, I may mention the great care and ability with which they were made; they will form the subject of the next paper.

The experiments on the tensile and compressive forces of the metals, and those on the transverse strain read at Bristol, were made by myself and are given below.

Tensile strength of Hot and Cold Blast Cast Iron.—To determine the direct tensile strength of the different kinds of cast iron made use of in these experiments, a model was made of the same form as I had previously used in some experiments on cast iron, of which a notice was given in the Cambridge volume of the Association. The castings from this model were very strong at the ends, in order that they might be perfectly rigid there, and had their *transverse* section for about a foot in the middle of the form annexed . This part, which was weaker than the ends, was intended to be torn asunder by a force acting perpendicularly through its centre. The ends of the castings had eyes made through them, with a part more prominent than the rest in the middle of the casting where the eye passed through. The intention of this was that bolts passing through the eyes, and having shackles attached to them by which to tear the casting asunder, would rest upon this prominent part in the middle, and therefore upon a point passing in a direct line through the axis of the casting.

Several of the castings were torn asunder upon the machine

for testing iron cables belonging to the Corporation of Liverpool. Others were made in the same manner but of smaller transverse area; these were broken by means of Mr. Fairbairn's lever, which was adapted so as to be well suited for the purpose.

The form of casting here used was chosen to obviate the theoretical objections made by Tredgold and others against the conclusions of former experimenters. The results are in the following table:

Results of Experiments on the Tensile Force of Cast Iron.

Description of Iron.	Area of section in inches.	Breaking weight in lbs.	Strength per square inch of section.	Mean in lbs. per square inch. Tons. cwts.
Carron Iron, No. 2, Hot Blast	4·031	56000	13892	13505 = 6 0½
Do. do. do.	1·7236	22395	12993	
Do. do. do.	1·7037	23219	13629	
Carron Iron No. 2, Cold Blast	1·7091	28667	16772	16683 = 7 9
Do. do. do.	1·6331	27099	16594	
Carron Iron, No. 3, Hot Blast	1·7023	28667	16840	17755 = 7 18½
Do. do. do.	1·6613	31019	18671	
Carron Iron, No. 3, Cold Blast	1·6232	22699	13984	14200 = 6 7
Do. do. do.	1·6677	24043	14417	
Devon (Scotland) Iron, No. 3, Hot Blast	4·269	93520	21907	21907 = 9 15½
Buffery Iron, No. 1, Hot Blast	3·835	51520	13434	13434 = 6 0
Do. do. Cold Blast	4·104	71680	17466	17466 = 7 16
Coed-Talon (North Wales) Iron, No. 2, Hot Blast	1·586	25818	16279	16676 = 7 9
Do. do. do.	1·645	28086	17074	
Do. do. Cold Blast	1·535	30102	19610	18855 = 8 8
Do. do. do.	1·568	28380	18100	

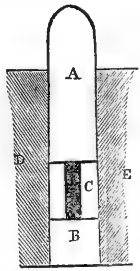
Compression, or the power to resist a crushing force.—In these experiments I shall confine myself to the resistance of short specimens; crushing, with few exceptions, only such as will break without bending. And if I should appear to pursue this and some other matters beyond the strict limits of the inquiry respecting the strength of hot and cold blast iron, I trust it will be excused, as my wish is to obtain some fixed principles where we have nothing but doubt and uncertainty.

The tensile strength of cast iron is still a matter of dispute: the few direct experiments by Mr. Rennie and Captain Brown

give from 7 to 9 tons per inch, results not widely differing from those above; they are noticed with some suspicion by Mr. Tredgold (Essay on Strength of Cast Iron, pages 91 and 92), who concludes from reasoning on the transverse strength of cast iron, according to the theory which he had adopted, that the direct tensile strength must be 20 tons or more. Mr. Barlow too, whose reasoning has better foundation than Tredgold's, concludes, whilst he gives these gentlemen's results, that the strength must be upwards of 10 tons per square inch, (Treatise on the Strength of Timber and other Materials, art. 123). I am not aware of any objection which can be brought against the tensile results given above, except some slight error which Mr. Barlow conceived (in his earlier work on the Strength of Timber, &c.) might arise from the use of testing machines, and that, in this case, would affect but four of the experiments; all the rest were made upon Mr. Fairbairn's lever. I hope to explain the cause of this difference of opinion among our ablest inquirers at a future meeting.

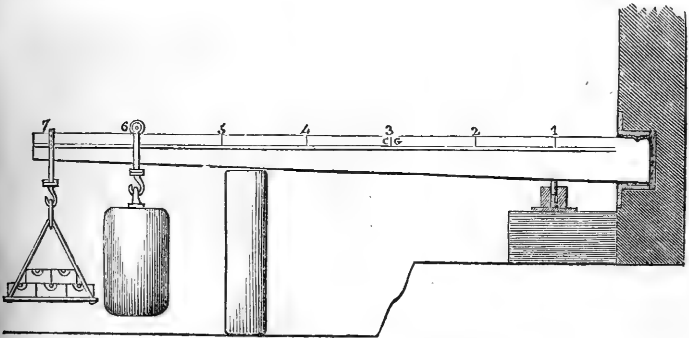
The resistance of materials to a crushing strain is equally a matter of doubt. Rondelet found (*Traité de l'Art de bâtir*) that cubes of malleable iron, and prisms of various kinds of stone, were crushed with forces which were directly as the area, whilst from Mr. Rennie's experiments, both upon cast iron and wood, it would appear that the resistance increases, particularly in the latter, in a much higher ratio than the area, (Mr. Barlow's Treatise, Art. 112). I have endeavoured, by repeating with considerable variations the ingenious experiments of Mr. Rennie, to arrive at some definite conclusions.

In order to effect this, it was thought best to crush the object between two flat surfaces, taking care that these were kept perfectly parallel, and that the ends of the prism to be crushed were turned parallel and at right angles to their axis, so that when the specimen was placed between the crushing surfaces its ends might be completely bedded upon them. For this purpose a hole $1\frac{1}{4}$ inch diameter was drilled through a block of cast iron about 5 or 6 inches square, and two steel bolts were made which just filled this hole, but passed easily through it; the shortest of these bolts was about $1\frac{1}{4}$ inch long, and the other about 5 inches; the ends of these bolts were hardened, having previously been turned quite flat and perpendicular to their axis, except one end of the larger bolt which was rounded. The specimen was crushed between the flat ends of these bolts, which were kept parallel by the block



of iron in which they were inserted. See fig. where A and B represent the bolts, with the prism C between them, and D E the block of iron. During the experiment the block and bolt B rested upon a flat surface of iron, and the rounded end of the bolt A was pressed upon by the lever. There was another hole drilled through the block at right angles to that previously described; this was done in order that the specimen might be examined during the experiment, and previous to it, to see that it was properly bedded.

The accompanying sketch will show more clearly the mode of performing the experiment, in which the lever was always kept as nearly horizontal as possible. Other apparatus, not here shown, were used to lift up or lower the lever during the experiments.



The results are given in the following tables:

Tabulated results of experiments made to ascertain the weights necessary to crush given cylinders, &c., of Cast Iron, of the quality No. 2, from the Carron Iron Works. The specimens in the three first columns of results, both in the hot and cold blast irons, were from cylinders cast for the purpose and turned to the right size; the $\frac{1}{2}$ inch from those of about $\frac{3}{4}$ inch, &c.

TABLE 1st.—HOT BLAST IRON.

Height of Specimens.	Cylinder, $\frac{1}{4}$ inch diameter; Crushing weight.	Cylinder, $\frac{3}{8}$ inch diameter; Crushing weight.	Cylinder, $\frac{1}{2}$ inch diameter; Crushing weight.	Cylinder, ·64 inch diameter; Crushing weight.	Right prism, base a square $\frac{1}{2}$ inch the side, cut out of an inch square bar; Crushing weight.	Right prism, base a rectangle 1·00 × ·26 inch, cut out of the middle of a bar $1\frac{1}{4}$ inch square.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{1}{8}$ inch	8737, 8145 } (a)	18882 (b)	30461 (c)			
$\frac{1}{4}$ do.	6658, 7103 } Mean 6880 (d)	14850, 17538 } Mean 16194	25169 (e)			
$\frac{3}{8}$ do.	6658, 6468 } Mean 6563	13282	25169			
$\frac{1}{2}$ do.	6405, 6405 } Mean 6405	13282	23797, 24189, 23993 } Mean 23993		25365, 26149 } Mean 25757	27788
$\frac{5}{8}$ do.	6341, 6278 } Mean 6309	13730		38671		
$\frac{3}{4}$ do.		15522, 15662 } Mean 15592	21522	35888	23797	
$\frac{7}{8}$ do.				35888		
1 do.		15564	21053, 21053 } Mean 21053			24764
$1\frac{1}{4}$ do.			23869			
$1\frac{1}{2}$ do.		14584	23053			
2 do.		13800	21828			

(*a*) not crumbled, flattened; (*b*) flattened and cracked round the edges; (*c*) reduced in thickness to about half, and cracked round the edges; (*d*) crushed; (*e*) reduced and cracked round the edges.

In all cases where the crushing weight is given without any remark, we may conceive the fracture to have taken place by a wedge sliding off from one of the ends, having the whole end for its base. The rectangles in the last column broke differently, a wedge nearly equilateral formed

Height of Specimens.	Cylinders $\frac{1}{4}$ inch diameter. Crushing weight.	Cylinders $\frac{3}{8}$ inch diameter. Crushing weight.	Cylinders $\frac{1}{2}$ inch diameter. Crushing weight.	Right prisms, base an equilateral Triangle, circumscribing a $\frac{1}{2}$ inch cylinder, its sides being ·866 inch. Crushing weight.	Right prisms, base a square, $\frac{1}{2}$ inch the side. Crushing weight.	Right prisms, base a rectangle 1·00 × ·243 inch.	Remarks.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
$\frac{1}{4}$ inch	6738, 6774 } Mean 6756	17034 (*a*)	28798 (*b*)				(*a*). With this weight the specimen was flattened in the middle and crushed round the edges. (*b*). The specimen was reduced in thickness to $\frac{1}{10}$ of an inch, and broken round the edges.
$\frac{3}{8}$ do.		14190	27230(*c*), 26838 } Mean 27034				(*c*). Crushed except the centre.
$\frac{1}{2}$ do.	6197, 6197 } Mean 6197	13994 (*e*)	24388, 24682 } Mean 24535	35548 (*d*)	27042, 24780, *25270 } Mean 25697	26587	(*d*). Fracture, a pyramid, splitting the three sides, one base whole, and the vertex of this base shown in the other. (*e*). Bulged out in the middle before breaking.
$\frac{5}{8}$ do.		14582					
$\frac{3}{4}$ do.	5908, 6053 } Mean 5980	13994	24486, 24388 } Mean 24437	33448	24780, *23996 } Mean 24388	26587	
1 do.	5764, 5836(*g*) } Mean 5798	14190	24780, 24584 } Mean 24682	31348 (*f*)	24296, *23604 } Mean 23950	25538	(*f*). Fracture by the ends forming the bases of pyramids meeting in the centre and throwing out the corners. See drawing. (*g*). Specimen slightly bent; wedge ·46 inch long.
$1\frac{1}{4}$ do.		14190	24486				
$1\frac{1}{2}$ do.		13702 (*h*)	23604(*i*), 23702 } Mean 23652				(*h*). Pillar bent a little, cracked across the middle; no alteration previous to fracture. (*i*). Bent a little with about a ton less than what broke it.

The specimens in the first column were turned out of a bolt $\frac{5}{8}$ inch diameter. All the specimens in the three last columns were out of the centre of a bar $1\frac{1}{4}$ inch square, except those marked *, which were from the middle of an inch bar. The wedges broken off from three of the longest cylinders $\frac{3}{8}$ inch diameter measured in length ·56, ·50, ·52 inch respectively. Two wedges from the $\frac{1}{2}$ inch cylinders, 1 inch high, measured ·68 and ·65 inch in length.

By comparing the results in the two preceding tables, it will be seen that, where the length is not more than about three times the diameter, the strength for a given base is pretty nearly the same, as has been shown by Mr. Rennie and others. In that case, the prism, in cast iron at least, either does not bend before fracture, or bends very slightly, and therefore the fracture takes place by the two ends of the specimen forming cones or pyramids, which split the sides, and throw them out; or, as is more generally the case in cylinders, by a wedge sliding off, starting at one of the ends, and having the whole end for its base, as has been before mentioned; this wedge being at an angle dependent upon the nature of the material. In cast iron, this angle is, as will be seen further on, such that the height is somewhat less than $\frac{3}{2}$ of the diameter; if the height of the specimen is less than the length of the wedge, the resistance is somewhat increased, and if the height be greater than from three to four times the diameter, the resistance, on account of the flexure of the specimen, will be decreased. In estimating the strength of the iron from the above tables, I shall mostly confine myself to such specimens as vary from about the length of the wedge to twice its length, avoiding such results as are reduced by flexure. Taking then the results from the cylinders and prisms of different dimensions of base, giving the means, with the number of experiments from which they were taken, we have the following abstracts:

FROM TABLE I.—HOT BLAST.

Diameter of cylinder.	Number of experiments.	Mean crushing weight.	Mean crushing weight per square inch.	General mean per square inch.
		lbs.	lbs.	
$\frac{1}{4}$	3	6426	130,909	121,685 lbs. = 54 tons $6\frac{1}{2}$ cwt.
$\frac{3}{8}$	4	14,542	131,665	
$\frac{1}{2}$	5	22,110	112,605	
$\frac{16}{25} = \cdot 64$	1	35,888	111,560	
Prism, base ·50 inch square.	3	25,104	100,416	100,738 lbs. = 44 tons $19\frac{1}{2}$ cwt.
do. base $1\cdot 00 \times \cdot 26$	2	26,276	101,062	

FROM TABLE II.—COLD BLAST.

Diameter of cylinder in parts of an inch.	Number of experiments.	Mean crushing weight.	Mean crushing weight per square inch.	General mean per inch.
		lbs.	lbs.	
$\frac{1}{4}$	2	6088	124,023	125,403 lbs. = 55 tons $19\frac{1}{2}$ cwt.
$\frac{3}{8}$	4	14,190	128,478	
$\frac{1}{2}$	7	24,290	123,708	
Equilateral triangle side ·866.	2	32,398	99,769	100,631 lbs. = 44 tons $18\frac{1}{2}$ cwt.
Squares, $\frac{1}{2}$ inch the side.	2	24,538	98,152	
Rectangles, base 1·00 × ·243.	3	26,237	107,971	
Cylinders ·45 inch diameter and ·75 high (not in table).	2	15,369	96,634	

The prisms, whose bases were triangles, squares, rectangles, and the cylinders, last mentioned, were all cut out of the centre of a bar $1\frac{1}{4}$ inch square.

It will be noticed that the cylinders in both the tables give much higher results per square inch than we have just found from the specimens cut out of the $1\frac{1}{4}$ inch bar. This the writer is inclined to attribute to no other cause but that they were mostly turned out of small cylinders cast for the purpose, which caused them to be harder than those from the middle of a larger mass.

We will defer speaking of such comparative results as affect the general question of hot and cold blast iron, till all the evidence is obtained which the present paper will afford; drawing however, as we proceed, such other conclusions as seem to be made out from the experiments.

Taking the mean crushing weight per square inch, as just obtained in the abstracts from the different cylinders in the 1st and 2nd tables, and retaining only the three first figures, we have

From 1st table, diameter	$\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{16}{25}$	Strength per inch.	131, 132, 113, 112.
From 2nd do.	$\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$		124, 128, 124.

The strengths per square inch in each of these lines approach to an equality, particularly in the latter, where the areas of section vary as 1 : 4; and the strength per inch is in both cases represented by 124. In the former line the cylinders of $\frac{1}{4}$ and $\frac{16}{25}$ inch diameter give strengths varying as 131 to 112 per square inch. The areas here vary nearly as 1 : 6·5, and the falling off in strength is about one-sixth. This small diminution in the power of the larger cylinders to resist crushing, may be accounted for from those having been cut

out of a larger body of metal than the small ones; a matter which we have seen greatly reduces the strength.

Admitting, then, that the strength per square inch in each of the preceding cases would have been the same if the iron had always been of equal hardness, we must conclude that "the resistance of short cylinders of cast iron to a crushing force is directly as the area."*

If we refer to the abstract from tables 1 and 2 for the mean strengths per square inch, as given by the equilateral triangle, the square, the rectangle, and the cylinder, we shall find them

in the latter, 99,769, 98,152, 107,971, 96,364;
in the former, 100,416, 101,062.

The strength, 107,971 and 101,062, as given by the prisms whose base is a rectangle, is the greatest;† and this may be accounted for from their superior breadth to that of the other specimens, and consequently, from their having in them more of the outside and harder part of the bar, out of which they were cut, than the others. In the other forms the difference of strength is but little; and therefore we may perhaps admit that "difference of form of section has no influence upon the power of a short prism to bear a crushing force."

Mode of Fracture. (See Plate.)

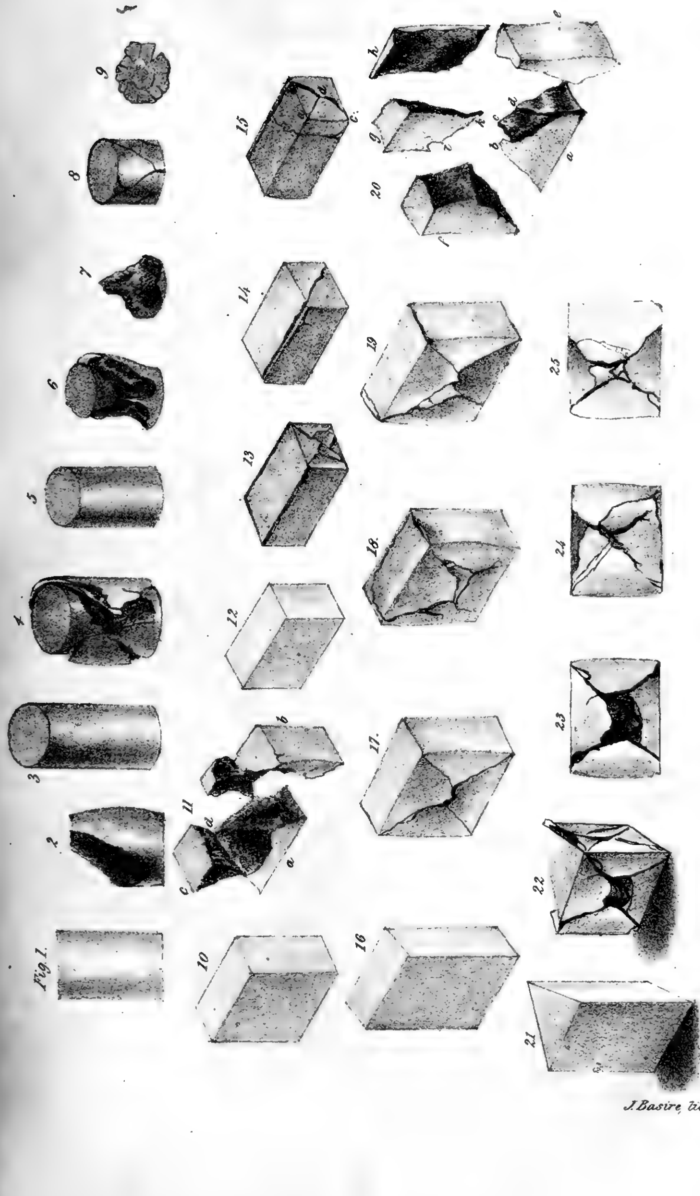
When a rigid body is broken by a crushing force, which is prevented from acting after it has effected a rupture, it will be found not to be crumbled or reduced to a shapeless mass, but to be divided according to mathematical laws, and sometimes into very interesting forms of fracture. The accompanying plate will show how the fracture was effected in a variety of cases, and that these were all subject to one pervading law. The figures in the plate are of the same size as the specimens. Fig. 1 represents a cylinder before it was crushed; fig. 2

* Conceiving it desirable that this matter should be left without a doubt, and as Mr. Fairbairn had some very good teakwood which had been many years in store, 12 cylinders were turned whose diameters were $\frac{1}{2}$ inch, 1 inch, and 2 inches, 4 of each; the latter 8 out of the same piece of wood; the height in each case was double the diameter: the strengths were as below.

Cylinders $\frac{1}{2}$ inch dia.		Cylinders 1 inch dia.		Cylinders 2 inches dia.	
2335	Mean 2439	10507	Mean 10171	38909	Mean 40304
2543		9499		39721	
2543		10507		41294	
2335		10171		41294	

These quantities, taking the means, are nearly as 25,100 and 400, which is the ratio of the areas, and therefore the strength is nearly as the area, though this varies as 4 and 16 to 1.

† Rondelet (*Traité de l'Art de bâtir*, book 9, page 150) found that prisms of stone, whose base was a rectangle, as above, bore somewhat *less* than those with square bases of the same area.



J. Basire, lith.

represents a wedge broken off from the same cylinder, the point of the wedge being flattened by the crushing apparatus after the fracture. There is a small crack in this wedge indicating a disposition to slide off in another direction, or rather to form a double wedge, nearly equilateral, having the diameter of the end of the cylinder for its base, and its height about half that of the former. The operation of this double wedge would be to split the cylinder and throw out its two sides. Figs. 3 and 4 represent another cylinder before and after crushing; in fig. 4, a double wedge formed at each end threw out the opposite sides. Figs. 5 and 6 represent a cylinder before and after crushing; in the latter, as in fig. 4, the ends of the figure have formed the bases of imperfectly formed cones, whose tendency has been to separate the sides. Fig. 7 is intended to represent one of these cones, the vertex of which is a sharp edge or point. Fig. 8 represents another cylinder of rather soft iron; the pressure was removed in the commencement of the fracture, and the circumference was found to be surrounded with parallel cracks both ways; the angle of these cracks with the base being that of the usual inclination of the wedge. Fig. 9 represents the appearance of a very short cylinder after fracture; the vertex of the cone, formed upon the end not shown, has split the end here represented, leaving a part in the middle unbroken; the opposite end is sound for a much greater central area than this, but its edges are a little broken.

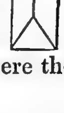
Fig. 10 represents a rectangle;* and fig. 11 its appearance after fracture. One end of the specimen has been formed into a pyramid A, sharp pointed at D, which has split the opposite base and thrown off the end B, and the part C very nearly. The sides and angular piece at the end are lost.

Fig. 12 represents a short rectangle before crushing; figs. 13, 14, 15, the different appearances of specimens of the same size after fracture. In fig. 14 the fracture has been caused by a sliding off in the way of the diagonal; in fig. 15 the specimen slided off in the direction *b c*, as before, and was cracked through its whole length in the direction *a d*; in fig. 13, the top of the specimen formed the base of a wedge which had split the bottom, and the bottom itself had formed the base of a wedge. Fig. 16 represents a rectangle of the same base as the preceding, but of double the height. Figs. 17, 18, 19, 20, represent its appearances as shewn by different specimens after fracture. Fig. 20, in which the parts are separated, shows a wedge A C D, which has for its base the bottom of

* The prism is, in this and many other places, designated by the form of its base.

the prism; this wedge has, commencing at its vertex C, a sharp line C D, $\frac{1}{4}$ inch long; and by the operation of its sides, the wedge has removed the parts E and F, and separated the sides G and H, which before joined together at the top and formed part of the upper side of the prism. The part A B, adhering to the lower part of the wedge, and which had formed part of the side of the prism, was nearly separated by the action of another wedge formed by the lower end of the part G, which formed a wedge not represented by the figure, but whose vertex formed a sharp line about ·43 inch long in the direction I K. This wedge occupied the space between B and C D, and its tendency was to split off from the principal wedge the only remaining portion A B.

Fig 21 represents a prism of the form of an equilateral triangle, and fig. 22 is its appearance after fracture. The tendency is here, as before, for opposite wedges to be formed, which split off the angles and separate the sides. Figs. 23, 24, 25, give direct representations of the three sides.

Angle of Wedge.—We have seen that when bodies are subjected to a crushing force, their fracture, if they do not break by bending, is caused by the operation of a cone or wedge, which seems, under various circumstances, to slide off at nearly a constant angle. If a prismatic body, as for instance a short cylinder, be subjected to a crushing force, there seems no reason why fracture should take place one way more than another; there is usually too in soft irons a bulging out in every direction round the cylinder, which shows that it is equally strained all round: a matter which is otherwise exemplified in fig. 8. If then the cylinder be longer than the wedge, or than the two cones which are always in operation at the ends during crushing, it is evident that the angle of the wedge and cones, which is the same, will depend upon the nature of the material, and the cones must be isosceles. Cylinders longer than the wedge usually slide off in one direction without showing the cones, but some examples in other forms have been obtained; as for instance, in the fracture of a rectangular specimen whose base was $1{\cdot}00 \times {\cdot}26$, and its height ·50 inch (Table I.), the rupture took place by wedges, which appeared to be isosceles, being formed at the top and bottom of the ends of the specimen, and dividing the sides in the middle, (as in the fig.  .)

In cases however where the height of the specimen was not

equal to that of the two opposing or double wedges, then these cones and wedges could not be isosceles after fracture commenced. It is shown by several of the figures (figs. 4, 6, 11, 13, 20, &c.) how fracture takes place, and that in such cases the wedges do not meet directly and crush their opponents, but have sharp points and slip past each other to effect the destruction of the piece of which they are formed. It is evident therefore that the angles, which the sides of these wedges make with their base, cannot in this case be equal; this is shown by the rectangles one inch high, and it was found to exist in a higher degree in the fracture of those of half the height. In these the angle with the base was further reduced, through an almost necessary tendency of the specimen to divide itself in the diagonal; though the angle there was less, on account of the compression of the prism, than the natural angle in this material. The angle of the wedge as obtained from different specimens is as follows :

Cylinders.

Carron Iron, No. 2, 54° 15′, 54° 15′, 52° 10′, 59°, 56° 15′	Mean	55° 11′
Buffery Iron, No. 1, 58°, 54°, 56°, 58°, 56°, 62°, 56°	Do.	57° 8′
Coed-Talon, No. 2, 55°, 56°, 56°, 53½°, 53°, 49°	Do.	53° 40′
Mean angles from cones 56½°, 54½°, 57½° .	Do.	56° 10′
Mean from the whole, being 21 cylinders of various lengths		55° 32′

Rectangular prisms 1 inch high, Carron Iron, No. 3, angles made by the sides of the double wedge, with the base.

Cold Blast 54°, 58

Hot Blast 58½, 57 ; 55½°, 60 ; 53° ; 54½°, 60 — Mean 56° 43′

Rectangular prisms ½ inch high, Carron Iron,
48°, 51°, 52°, 54°, 57°, 52°, . . . Mean 52° 40′

Mean angle from the above rectangular prisms . 54° 41′

Prisms, Base ·50 × ·50 inch.

Carron Iron, No. 2. . . . 53°, 54° . Mean 53° 30′

From the preceding examination of the angles obtained from specimens of different forms and lengths, it appears that amidst great anomalies, there is, taking the *mean* results, a considerable approach to equality, as is more particularly shown from the angles of the cylinders and rectangular prisms; and this approach would doubtless have been greater and the anomalies less if the specimens had always been longer than the wedge. The defect in the angle from this cause is evident in the shorter rectangular prisms, and has been alluded to before.

We may assume therefore, without assignable error, that in the crushing of short cast iron prisms of various forms, longer than the wedge, the angle of fracture will be the same. This simple assumption, if admitted, would prove at once, not only in this material but in others, which break in the same manner, the proportionality of the crushing force in different forms to the area; since the area of fracture would always be equal to the direct transverse area multiplied by a constant quantity dependent upon the material.

The preceding experiments on crushing have been confined to one sort of iron, the Carron No. 2, hot and cold blast. The results from other irons are given in the following table:—

Compression.—Table, No. 3.

Result of Experiments to ascertain the forces necessary to crush short cylinders, &c. of cast iron, from various parts of the United Kingdom. All the cylinders were turned out of bars cast 1 inch square, and the rectangular prisms were cut out of the castings broken in the experiments on tension.

Devon (Scotch) Iron, No. 3. Hot Blast.

Height of specimen.	Cylinder Diameter ·505 inch.	Cylinder Diameter ·380 inch.
	Crushing weight in lbs.	Crushing weight in lbs.
$\frac{3}{4}$ inch.	31,138	15,323
1 "	30,438	15,789
Mean from above	30,788	15,556
Mean per square inch.	153710	137160
Mean per sq. inch from the whole.	145,435 lbs. = Tons. 64 Cwts. $18\frac{1}{2}$	

Buffery (near Birmingham) Iron, No. 1.

	Height of specimens.	Crushing weight in lbs.	Mean crushing weight per square inch in lbs.
Hot Blast. Diameter of cylinder ·505 inch.	$\frac{1}{2}$ inch.	17,823	
	1 "	17,039	
	$1\frac{1}{2}$ "	17,431	
	2 "	16,927	
	Mean	17,305	86,397 = Tons. 38 Cwts. $11\frac{1}{4}$
Cold Blast. Diameter of cylinder ·506 inch.	$\frac{1}{2}$ inch.	18,271	
	1 "	18,943	
	$1\frac{1}{2}$ "	19,615	
	2 "	18,271	
	Mean	18,775	93,385 = Tons. 41 Cwts. $13\frac{1}{2}$

Coed-Talon (Welsh) Iron, No. 2.

	Height of specimens.	Crushing weight in lbs.	Mean crushing weight in lbs. per sq. inch.
Hot Blast. Diameter of cylinder ·6075 inch.	$\frac{1}{2}$ inch.	25,541	
	1 "	24,278	
	$1\frac{1}{2}$ "	23,228	
	2 "	22,878	
	Mean	23,981	82,734 = Tons. 36 Cwts. $18\frac{1}{2}$
Cold Blast. Diameter of cylinder ·6025 inch.	$\frac{1}{2}$ inch.	24,978	
	1 "	22,528	
	$1\frac{1}{2}$ "	22,878	
	2 "	22,878	
	Mean	23,313	81,770 = Tons. 36 Cwts. 10

Carron (Scotch) Iron, No. 2. Right Prisms, area of base $\frac{3}{4} \times \frac{1}{3} = \frac{1}{4}$ inch.

	Height of specimens.	Crushing weight in lbs.	Mean crushing weight in lbs. per square inch.
Hot Blast.	·50	27,541	
	1·00	26,729	
	Mean	27,135	108,540 = Tons. 48 Cwts. 9
Cold Blast.	·50	28,353	
	1·00	25,511	
	1·00	25,917	
	Mean	26,593	106,375 = Tons. 47 Cwts. $9\frac{3}{4}$

Carron (Scotch) Iron, No. 3. Right Prisms, area of base $\frac{3}{4} \times \frac{1}{3} = \frac{1}{4}$ inch.

	Height of specimens.	Crushing weight in lbs.	Mean crushing weight in lbs. per square inch.
Hot Blast.	·50	34,037	
	·75	33,631	
	1·00	32,413	
	Mean	33,360	133,440 = Tons. 59 Cwts. $11\frac{1}{4}$
Cold Blast.	·50	29,165	
	·50	29,571	
	1·00	27,541	
	1·00	29,165	
	Mean	28,860	115,442 = Tons. 51 Cwts. $10\frac{3}{4}$

Ratio of Tensile to compressive forces in Cast Iron.

Having obtained the forces per square inch necessary to tear asunder and to crush masses of cast iron of the kinds previously enumerated, we will seek for the ratio of these forces, taking the breaking weights from the preceding table and that on tension.

Description of metal.			Compressive force per square inch.	Tensile force per sq. inch.	Ratio.
Devon Iron,	No. 3.	Hot blast	145,435	21,907	6·638 : 1
Buffery Iron,	No. 1.	Hot Blast.	86,397	13,434	6·431 : 1
do.	No. 1.	Cold Blast.	93,385	17,466	5·346 : 1
Coed-Talon Iron,	No. 2.	Hot Blast.	82,734	16,676	4·961 : 1
do.	„	Cold Blast.	81,770	18,855	4·337 : 1
Carron Iron,	No. 2.	Hot Blast.	108,540	13,505	8·037 : 1
do.	„	Cold Blast.	106,375	16,683	6·376 : 1
Carron Iron,	No. 3.	Hot Blast.	133,440	17,755	7·515 : 1
do.	„	Cold Blast.	115,442	14,200	8·129 : 1

Before quitting the subject of compression, I may mention that, in experiments upon various bodies besides cast iron, a tendency to form cones or pyramids in the fracture was observable, showing that the same laws were in operation in these as have been developed in the experiments upon cast iron. For instance, in the crushing of short cylinders of bone obtained from the thigh of an ox, fracture always took place by cones or wedges. In marble the same result was frequently observable, though less obvious than in iron, through a disposition to split in the direction of the strata.

On the power of timber of various kinds to resist a crushing force, I have, through the liberal views of Mr. Fairbairn, made a considerable number of experiments, with an apparatus similar to that employed in the crushing of cast iron, but much larger. In this material, though fibrous, fracture always took place by wedges sliding off, or by cones or wedges splitting the prism in the manner of cast iron, though at a much less angle with the horizon than in that metal. In the crushing of malleable iron likewise, short specimens always bulge out in the middle through the operation of the opposing cones or pyramids formed at their bases.

As this principle is found to obtain in the crushing of short bodies so widely different as bones, marble*, timber of all kinds,

* Rondelet (*Traité de l'Art de bâtir*) crushed stones of various kinds, and has given the forms of pyramids obtained from crushing prisms with square bases.

cast iron, malleable iron, we may therefore assume that it is in operation in the crushing of all rigid bodies, and consequently that, in any particular one, the resistance will be as the area of its section.

I may perhaps mention that this subject ought to be studied in conjunction with optics and crystallization. The singular structure of the mineral called analcime, or cubizite, as shown by polarized light, and given by Sir David Brewster, Optics, chap. xxv., has so much the appearance of some of our fractures, as to lead one to conceive that it may have arisen from compression.

Transverse strength.—It is to ascertain the resistance of materials to a transverse strain that the efforts of experimenters have chiefly been directed. One reason for this seems to be the great facility with which bodies can be broken this way comparatively with others, which require large weights or complex machinery, and often considerable attention to theoretical requirements.

In making the following experiments, it has been the author's aim, whilst he kept in view the inquiry respecting hot and cold blast iron, to make the results subservient to some other purposes, besides giving an extended view of the application of these irons.

As the inquiry was a comparative one, and required that a number of experiments, and those similar to each other, should be made upon each iron from any particular place, several models were made, and castings, both of hot and cold blast iron, obtained from them; and as it seemed desirable to trust in these experiments as little as possible to theory, some bars, one inch square, were always obtained from the same model. From these, and from others, a satisfactory comparison of the relative strengths of the irons would have been obtained without the use of theory, could the castings have always been got of the exact size of the model; but as small deviations in this respect were unavoidable, theory was employed to effect the slight reduction in the results of each bar to what they would have been if the bars had been of the exact dimensions of the models.

All the bars used in these comparisons are uniform and of the same length, and the theoretical assumptions with regard to the strength and deflection are of the simplest and most generally admitted kind. They are as below, the strength in rectangular bars is taken as the breadth multiplied by the square of the depth, and the ultimate deflection is supposed to be inversely as the depth. To these there has been added

another, namely, that the power of bearing an horizontal impact from a given weight is measured by the strength of the beam multiplied by its ultimate deflection. This last assumption supposes that all cast-iron bars of the same dimensions in our experiments are of the same weight, and that the deflection of a beam up to the breaking weight would be as the pressure. Neither of these is true, they are only approximations; but the difference in the weights of cast-iron bars of equal size is very little, and taking them as the same, it may be inferred from my paper on Impact upon Beams (Fifth Report of the British Association), that the assumption above gives results near enough for practice.

After the following tables, therefore, there will always be given a summary of the strengths and deflections, reduced to what they would have been supposing the bar to be of the exact size of the model; and attached to these there will be the other values mentioned above, representing the power of the beam to bear impact.

The modulus of elasticity is set down that it may serve as a measure of the comparative stiffness of the irons. It is given in pounds per square inch.

The ultimate deflection attached to each experiment was derived from the results last obtained, and as these results were usually more numerous than those set down, the deflection cannot often be calculated from those which remain, but is nearer to the truth than those which might be obtained from the remaining ones.

In all the future experiments, the bars were cast 5 feet long, and were supported on props 4 feet 6 inches asunder, except it is otherwise mentioned, which will only be found in two cases.

In the prosecution of the experimental part of this research, it gives me great pleasure to acknowledge the efficient manner in which my views were carried into execution by Mr. John Patchett, an intelligent pupil of Mr. Fairbairn.

TABLE I.—Results of Experiments to ascertain the Transverse Strength of Carron Iron, No. 2. All the Castings were uniform throughout; they were cast 5 feet long (except otherwise mentioned), and supported during the experiments on props 4 feet 6 inches asunder; the pressure being applied in the middle. The weight of the bars, when given, are those of the whole length.

Hot Blast Iron, made with Coke.

Experiment 1. Rectangular bar 1·00 deep, 1·00 broad. Weight 15 lbs. 2 oz.

Weight in lbs.	Deflection in inches.	Set, or deflection when unloaded.
16	·037	visible
23	·052	increased
30	·070	·001?
56	·132	·002
112	·271	·008
224	·588	·037
336	·940	·087
448	1·360	·181
469	broke	

∴ Ultimate deflection = 1·444.

Experiment 2. Rectangular bar 1·017 deep, 1·010 broad. Weight 15 lbs. 11 oz.

Weight in lbs.	Deflection in inches.	Set.
23	·051	visible
30	·067	..
56	·129	·001
112	·261	·006
224	·561	·030
336	·900	·077
448	1·297	·153
476	broke	

∴ Ultimate deflection = 1·400.

Experiment 3. Rectangular bar ·996 deep, 1·002 broad. Weight 15 lbs. 3 oz.

Weight in lbs.	Deflection in inches.	Set.
16	·038	visible
23	·052	..
30	·070	·001?
56	·133	·004
112	·276	·009
224	·598	·040
336	·958	·094
448	1·388	·187
462	broke	

∴ Ultimate deflection = 1·446.

Experiment 4. Bar 7 ft. long supported on props 6 ft. 6 in. asunder.—Its form of section ⊤, broken as shown, with the rib downwards.

Weight in lbs.	Deflection in inches.	Set.
7	·015	visible
14	·032	·001?
21	·046	·002
28	·064	·004
56	·130	·005
112	·273	·020
168	·444	·035
224	·618	·058
280	·813	·093
336	1·030	·130
364	broke	

∴ Ultimate deflection = 1·138.

Experiment 5. Bar from the same model as the last, supported on props 6 ft. 6 in. asunder, broken with the rib upwards, thus, ⊥.

Weight in lbs.	Deflection in inches.	Set.
7	—	not vis.
14	·025	visible
21	·045	·002
28	·065	·003
56	·134	·005
112	·270	·015
224	·580	·058
336	·895	·101
448	1·224	·155
560	1·585	·235
672	1·985	·330
784	2·410	·490
896	3·450	·722
1008	4·140	1·040
1064	—	
1120	broke	

Fracture caused by a Wedge 2·92 inches long and 1·05 deep flying out of the form

∴ Ultimate deflection = 4·830.

Experiment 6. Bar 5 ft. long, broke on supports 4 ft. 6 in. asunder, same form as before, but smaller vertical rib broken with rib downwards, ⊤

Weight in lbs.	Deflection in inches.	Set.
112	·20	
168	·30	·01
196	·36	
224	·42	·02
252	·49	
280	broke	

∴ Ultimate deflection = ·55

Experiment 7. Bar same as the last, broke with the rib upwards, ⊥.

Weight in lbs.	Deflection in inches.	Set.
112	·20	
224	·40	
280	·50	·02
336	·60	
392	·72	·07
448	·84	
560	1·12	·18
672	1·47	
784	1·92	
896	2·55	
952	2·95	
980	broke	

Fracture caused by a wedge 4·9 ins. long flyihg out of the form

∴ Ultimate deflection = 2·15.

TABLE I. continued.

Experiment 8. Bar an isosceles triangle. Base 1·43 inch. Each side 2·00. Broke with the vertex downwards. ▽		
Weight in lbs.	Deflection in inches.	Set.
112	·07	
168	·11	
224	·15	·002
336	·24	·01
448	·33	·02
560	·44	·04
616	·50	
644	·53	
672	broke	
∴ Ultimate deflection = ·56.		

Experiment 9. Bar same as the last, filed to the exact size. Broke with vertex downwards as before. ▽		
Weight in lbs.	Deflection in inches.	Set.
112	·07	
168	·102	
224	·140	·002
336	·22	·01
448	·31	·015
560	·40	·03
672	·51	·05
784	·62	·08
812	broke	
∴ Ultimate deflection = ·65.		

Experiment 10. Bar same as the last, but one-tenth of the depth taken off the vertex. Broke with vertex downwards. ▽		
Weight in lbs.	Deflection in inches.	Set.
112	·075	
168	·11	·004
224	·15	·005
336	·24	·01
448	·34	·017
560	·44	·035
672	·55	·06
700	·59	
728	broke	
∴ Ultimate deflection = ·63.		

Experiment 11. Bar cast 1¼ inch square, and reduced in the middle to 1·019 deep, 1·021 broad.	
Weight in lbs.	Set.
112	·01
168	·025
224	·04
336	·10
392	·15
448	·21
504	broke

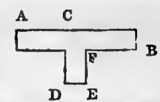
Experiment 12. Bar cast the same as last, and reduced in the middle to 1·013 deep, 1·017 broad.	
Weight in lbs.	Set.
112	·005
168	·02
224	·05
336	·15
392	—
448	broke

Experiment 13. Bar a rectangle, 3·00 inches deep and 1·03 ... broad.		
Weight in lbs.	Deflection in inches.	Set.
1082	·085	
1343	·106	+
1474	—	·001
1605	·130	·003
1866	·156	·006
2126	·185	·010
2388	·212	·012
2649	·243	·017
2910	·272	·022
3172	·307	·03
3433	·340	·038
3694	·378	·05
3956	broke	
∴ Ultimate deflection = ·416.		

Experiment 14. Bar a rectangle, 4·98 inches deep, 1·02 ... broad. Length 5 feet, Weight 78 lbs.		
Weight in lbs.	Deflection in inches.	Set.
5867	·127	
6798	·153	·01
7730	·177	
8661	·207	
9593	·235	
10524	·275	·03
11087	broke	
∴ Ultimate deflection = ·299.		

Experiment 15. Bar from the same model as the last. 4·97 inches deep, 1·02 ... broad. Weight 77 lbs.		
Weight in lbs.	Deflection in inches.	Set.
4936	·105	
5867	·133	·009
6798	·152	·01
7730	·190	
8662	·223	
9034	it bore	
9220	broke	
∴ Ultimate deflection = ·244.		

Notes. Two samples have been obtained of both the Hot and Cold Blast Carron Irons, No. 2. The first five experiments in Table 1, and the first three in Table 2, were from samples obtained after all the other experiments on this iron had been made; they perhaps give results a little higher than those previously obtained.



In experiments 4, 5, 6, 7, the transverse section of the casting may be represented by A, C, B, F, E, D, where A B and F D are parallelograms, each part being of uniform thickness. In experiments 4 and 5 the area of the parallelogram A B = 5 × ·30 inches, the thickness being ·30 inch. In the former of these experiments C D = 1·55, and D E (which may represent the uniform thickness of the rib D F) = ·36 inch. In the latter experiment C D = 1·56, and D E = ·365 inch. These two experiments were the only ones where the castings were more than 5 feet long. The castings in Experiments 6 and 7 give nearly as follows: Area A B = 5 × ·27 inch, C D = 1·27, D E = ·25 inch.

Results of the Rectangular Bars above reduced to those of Bars 1 inch broad, and 1, 3, and 5 inches deep. Distance between supports 4 feet 6 inches.

	Specific gravity.	Modulus of elasticity in lbs. per square inch.	Breaking weight in lbs. (b).	Ultimate deflection in inches (d).	Product $b \times d$ or power of resisting impact.
Experiment 1st, bar one inch deep and one inch broad	7020	16269000	469	1·444	677·2
Do. 2nd, do. do.		15901000	456	1·424	649·3
Do. 3rd, do. do.	...	...	465	1·144	532·0
	Mean	16085000	463	1·337	619·5
Do. 11th, do. do.	7031	...	475		
Do. 12th, do. do.	7008	...	429		
	Mean	...	452		
Do. 13th, three inches do.	...	...	3843	·416	1598·7
Do. 14th, five inches do.	7070	...	10957	·298	3265·2
Do. 15th, do. do.	7100	...	9149	·243	2223·2
Mean	7046	...	10053	·270	2744·2
Results of Experiments not reduced.					
Experiment 6th, bar-rib extended	...	...	280	·55	154·0
Do. 7th, do. compressed	...	...	980	3·15	3087·0
Do. 8th, Triangle	...	...	672	·56	376·3
Do. 9th, do.	...	...	812	·65	527·8
Mean	...	...	742	·60	452·0
Do. 10th, Frustum of do.	...	...	728	·63	458·6

Table II.—Results of Experiments on the Transverse Strength of Carron Iron, No. 2. Lengths of bars, and distance between the supports as before. Cold Blast Iron made with Coke.

Experiment 1. Rectangular bar 1·025 deep 1·002 broad. Weight, 15 lbs. 6 oz.

Weight in lbs.	Deflection in inches.	Set, or deflection when unloaded.
16	·033	visible
30	·062	increased
56	·12	·002
112	·24	·007
168	·37	·014
224	·51	·028
280	·649	·041
336	·798	·061
392	·953	·084
448	1·12	·12
504	1·31	·17
514	it bore	
518	broke	

∴ Ultimate deflection = 1·36. Broke $\frac{3}{4}$ of an inch from the centre.

Experiment 2. Rectangular bar 1·021 deep 1·015 broad. Weight, 15 lbs. 11 oz.

Weight in lbs.	Deflection in inches.	Set.
30	·061	visible
37	·076	increased
56	·115	·001 ?
112	·223	·002
168	·358	·011
224	·49	·019
280	·616	·032
336	·757	·05
392	·908	·073
448	1·068	·101
504	1·252	·147
532	it bore	
539	broke	

∴ Ultimate deflection = 1·367.

Experiment 3. Rectangular bar 1·040 deep 1·026 broad. Weight, 16 lbs. 2 oz.

Weight in lbs.	Deflection in inches.	Set.
16	·034	doubtful
23	·049	visible
56	·116	·005
112	·228	·008
168	·345	·011
224	·470	·018
280	·599	·030
336	·732	·047
392	·878	·069
448	1·030	·095
476	broke	

∴ Ultimate deflection = 1·106.

Experiment 4. Uniform bar. Form of section $\top$. Broke with the vertical rib downwards.

Weight in lbs.	Deflection in inches.	Set.
112	·03	...
224	·07	...
336	·11	...
392	·13	·005
420	·14	·007
448	·15	·01
560	·19	·012
672	·23	·015
784	·28	·023
896	·33	·03
952	·35	
980	broke	

∴ Ultimate deflection = ·36.

Experiment 5. Bar from same model as the last. Broke with the vertical rib upwards $\perp$.

Weight in lbs.	Deflection in inches.	Set.
112	·03	...
224	·07	...
336	·11	...
448	·15	...
560	·19	·005
616	·21	·01
672	·23	...
728	—	·015
784	·27	
896	·31	
1008	·35	
1120	·39	
1344	·48	
1568	·57	
1792	·67	
2016	·80	
2240	·95	
2296	it bore	
2352	broke	

∴ Ultimate deflection = 1·03. Fracture by a wedge breaking out as in experiment 5 Hot Blast.

Experiment 6. Bar from the same model as in experiment 6 Hot Blast. Broke with the rib downwards.

Weight in lbs.	Deflection in inches.	Set.
112	·19	...
126	·21	...
140	·26	...
154	·27	·01
168	·31	·015
182	·32	...
196	·37	...
210	·39	...
224	·43	·03
238	·46	...
252	·50	·045
266	broke	

∴ Ultimate deflection = ·53.

Experiment 7. Bar from the same model. Broke with the rib upwards.

Weight in lbs.	Deflection in inches.	Set.
112	·21	
168	·30	·01
224	·40	·025
280	·50	·03
336	·60	...
392	·71	·06
448	·82	...
560	1·09	·15
672	1·39	·26
784	1·76	·44
896	2·30	
1008	2·95	
1036	3·15	
1050	broke	

∴ Ultimate deflection = 3·23. Broke by the separation of a wedge, as in experiment 7 Hot Blast.

TABLE II. continued.

Experiment 8. Bar, whose section was an isosceles triangle, filed to a gauge same as in experiment 8 and 9 Hot Blast. Broke with vertex downwards.			Experiment 9. Bar same as the last, except its having $\frac{1}{10}$th taken off the vertex, as in experiment 10 Hot Blast. Broke with the vertex downwards.			Experiment 10. Bar cast $1\frac{1}{4}$ inch square, and reduced in the middle to 1·020 deep 1·020 broad.			Experiment 11. Bar cast the same as the last, and reduced in the middle to 1·014 deep 1·014 broad.			Experiment 12. Bar a rectangle 3·00 deep, 1·02 broad. Weight, 46 lbs. 8 oz.			Experiment 13. Bar a rectangle 4·98 deep 1·03 broad. Weight, 78 lbs.		
Weight in lbs.	Deflection in inches.	Set.	Weight in lbs.	Deflection in inches.	Set.	Weight in lbs.	Deflection in inches.	Set.	Weight in lbs.	Deflection in inches.	Set.	Weight in lbs.	Deflection in inches.	Set.	Weight in lbs.	Deflection in inches.	Set.
112	·07	...	112	·07	...	98	...	·003	98	...	·005	1082	·091	·003	4936	·110	·013
168	·105	·005	168	·11	...	112	...	·003	112	...	·005	1343	·111	·006	5867	·130	...
196	·120	·009	196	·125	...	140	...	·01	140	...	·01	1605	·138	·008	6798	·153	·02
224	·145	...	224	·15	...	168	...	·02	168	...	·02	1866	·164	·010	7730	·179	·025
280	·18	·01	238	—	·002	196	...	·03	196	...	·03	2126	·190	·012	8662	·195	...
336	·22	...	252	·165	·002	224	...	·04	224	...	·04	2388	·220	·015	9593	·219	·034
392	·26	...	280	·19	·002	336	...	·09	336	...	·13	2649	·250	·019	10525	·250	·042
448	·31	...	336	·23	·003	392	...	·13	392	...	·16	2910	·281	·026	10588	broke	
504	·36	...	392	·27	...	448	...	·19	448	...	·25	3172	·310	·031			
560	·41	·04	448	·32	·01	476	broke		476	broke		3433	·345	·037			
616	·45		504	·36	...							3694	·378	·046			
672	·51		560	·42	·025							3825	broke				
728	·56		616	·47													
784	·62		644	·50													
815	broke		677	broke													
∴ Ultimate deflection = ·65.			∴ Ultimate deflection = ·53.									∴ Ultimate deflection = ·395.			∴ Ultimate deflection = ·252.		

Note.—The dimensions of the bars in Experiments 6 and 7 were very nearly the same as those given in the note to the same experiments on the Hot Blast Iron. In these the thickness of the vertical rib was $\frac{1}{4}$ inch, and its depth 1 inch; the whole depth of the casting being 1·27. In Experiments 4 and 5 above, the area of a section of the casting was the same as in the others just mentioned, and the thickness of the parts nearly the same, but the vertical rib was of double the depth, or about 2 inches deep; the whole depth being about 2·27 or a little more. This rib, however, was slightly tapered towards the ends, and therefore the results from these experiments were not strictly comparable with those from the others.

Results of the Rectangular Bars above reduced to those of Bars 1 inch broad, and 1, 3, and 5 inches deep. Distance between supports 4 feet 6 inches.

	Specific gravity.	Modulus of elasticity.	Breaking weight in lbs. (b).	Ultimate deflection in inches (d).	Product $b \times d$ or power of resisting impact.
Experiment 1st, bar one inch deep and one inch broad	7087	17025000	492	1·394	686
Do. 2nd, do. do.	7082	17516000	509	1·396	711
Do. 3rd, do. do.			429	1·150	493
	Mean	17270500	476	1·313	630
Do. 10th, do. do.	{7139 / 7017}		449		
Do. 11th, do. do.	7008		457		
Mean	7066		453		
Do. 12th, three inches do.			3750	3·95	1481
Do. 13th, five inches do.			10362	·251	2601
Results of Experiments not reduced.					
Experiment 6th, bar-rib extended			266	·53	141
Do. 7th, do. do. compressed			1050	3·23	3391
Do. 8th, Triangle			815	·65	530
Do. 9th, Frustum of do.			677	·53	359

Note.—I have been favoured by Mr. Fairbairn with the annexed examination of the structure of this and the following Irons:—

"The Carron No. 2, cold blast iron, when viewed with the microscope, presents a dull grey colour, finely granulated with an appearance of greater porosity in the centre than round the extreme edges of the fracture. It is a free working iron, easily cut with the turning tool, but indicates stiffness under the file.

"Carron No. 2, hot blast. This iron has nearly the same character in its working properties as the above; it files with rather more freedom, and possesses an appearance of greater fluidity than the cold blast. Colour, a greyish blue, accompanied with a greater degree of uniformity in its crystalline structure than the cold blast.

"Buffery No. 1, cold blast, is finer grained than either of the Carron irons. It is chiefly composed of minute granules intermixed with small brown specks; it works with less freedom than the hot blast, and cuts with difficulty under the tool. In this respect it is much akin to the Milton iron (described in Mr. Fairbairn's paper).

"Buffery No. 1, hot blast, has a similar appearance to the Carron, No. 2, cold blast; it has more lustre than Buffery No. 1, cold blast; the crystals are widely separated in the centre, but more compact as they approach the outer edge of the bar.

"This appearance is nearly peculiar to the whole of the hot blast irons."

Remarks upon the Experiments in the preceding Tables.—In devising the preceding experiments the writer had several objects in view, which he will now proceed to state. It has been remarked above that the first five experiments on the hot blast iron, and the first three on the cold blast, in the tables above, were made after the others. These will therefore be passed over for the present, and we shall commence with experiments 6 and 7, which, like most of the others, are on bars from the same model in both tables. The object of these experiments was to show the influence of form of section in beams of cast iron; and it will be seen from the results, that when the rib was downwards, the casting broke with 280lbs. in the hot blast iron, and 266lbs. in the cold blast. When the rib was upwards, the breaking weights were 980lbs. and 1050lbs. respectively; the bars bearing nearly four times as much one way up as the other. These results are contrary to the opinions of some leading writers, as Tredgold and others, who, from their principles, would maintain that the strength should

be equal in the two cases. An experiment of this kind I gave in a paper on the strength and best forms of iron beams (Memoirs of the Literary and Philosophical Society of Manchester, vol. v.), and it formed indeed the basis of the inquiry in that paper.

I had remarked in some of the experiments upon the Carron iron, and more particularly the Buffery following, that the elasticity of the bars was injured much earlier than is generally conceived; and that instead of it remaining perfect till one-third or upwards of the breaking weight was laid on, as is generally admitted by writers (Tredgold on Cast Iron, Article 59, &c.), it was evident that $\frac{1}{5}$th or less produced in some cases a considerable set or defect of elasticity, and judging from its slow increase afterwards, I was persuaded that it had not come on by any sudden change, but had existed, though in a less degree, from a very early period. I mentioned the fact and my convictions sometime after to Mr. Fairbairn, and expressed a desire to have bars cast of greater length than before to render the defect more obvious.

All the future experiments on a transverse strain, whether made by myself or Mr. Fairbairn, have tended to prove the matter.

We passed over the experiments placed at the beginning of Tables 1 and 2: referring now to them, it will be seen, that in 3 out of 6 experiments, 16lbs. produced a visible set, whilst the breaking weights in these cases were 469, 462, 518: in other words, the elasticity was injured with $\frac{1}{30}$ of the breaking weight, or less. In experiments 4 and 5, Table I., which were on longer bars than the others, cast for this purpose, and for another mentioned further on, the elasticity in the former experiments was sensibly injured with 7lbs., and in the latter with 14lbs., the breaking weights being 364lbs. and 1120lbs. In the former of these cases a set was visible with $\frac{1}{52}$, and in the other with $\frac{1}{80}$ of the breaking weight, showing that there is no weight, however small, that will not injure the elasticity.

In two other bars, from the same model, which were laid against vertical supports at the same distance asunder as before, the force being applied horizontally by means of a pulley, 7lbs. showed a defect of elasticity in that which had the rib submitted to tension, and 21 in the other.

The mode used to observe when the elastic force became injured was as follows. When a bar was laid upon the supports for experiment, a "straight edge" was placed over it, the ends of which rested upon the bar directly over the points

of support. These ends were slides which enabled the straight edge to be raised or lowered at pleasure. In this manner it was easy to bring it down to touch in the slightest manner a piece of wood tied upon the middle of the bar. A candle was then placed at the side of the bar opposite to where the observer stood, by the light of which, distances extremely minute could be observed. Should it be asked why this had not been noticed before, the answer of the writer would be, that most experimenters have used bars shorter in proportion to their depth than are here employed, and therefore the set was much less obvious than here; and in deep bars or beams it is almost imperceptible till the weight laid on is considerable.

From what has been stated above, deduced from experiments made with great care, it is evident that the maxim of loading bodies within the elastic limit has no foundation in nature; but it will be considered as a compensating fact, that materials will bear for an indefinite time a much greater load than has hitherto been conceived.

When a body is subjected to a transverse strain some of its particles are extended and others compressed; I was desirous to ascertain whether the above defect in elasticity arose from tension or compression, or both. Experiments 4 and 5 show this; in these a section of the casting, which was uniform throughout, was the form 

. During the experiments the broad flat part *a b* was laid horizontally upon supports; the vertical rib *c* in the latter experiment being upwards, in the former downwards. When it was downwards the rib was extended, when upwards the rib was compressed. In both cases the part *a b* was the fulcrum; it was thin and therefore easily flexible, but its breadth was such that it was nearly inextensible and incompressible comparatively with the vertical rib. We may therefore assume that nearly the whole flexure which takes place in a bar of this form arises from the extension or compression of the rib, according as it is downwards or upwards. In experiment 4 we have extension nearly without compression, and in experiment 5 compression almost without extension. These experiments were made with great care, and their results are generally in accordance with those from two others alluded to above, but not inserted. They show that there is but little difference in the quantity of the set, whether it arises from tension or compression.

The set from compression however is usually somewhat less than that from extension, as is seen in the commencement of the two experiments, and near the time of fracture, in that

submitted to tension. The deflections from equal weights are nearly the same, whether the rib be extended or compressed, (as was shown by Duleau in experiments upon triangular bars of malleable iron,) but the ultimate strengths, as appears from above, are widely different.

It is to be hoped that the observations made above will obviate objections which have been offered against a form of cast iron beam arrived at by the writer, in a paper alluded to above. From this paper it appeared that a beam bore the greatest weight from the same quantity of metal when the strengths of its bottom and top ribs were as 6 or $6\frac{1}{2}$ to 1, and this was found in the subsequent experiments of the writer to be nearly the ratio of the tensile to the compressive strength of the iron.

To ascertain the correctness or otherwise of the assertion of Emerson, so often shown to be true in theory, that if a small portion be taken from the vertex of a beam whose section is a triangle, the part will be stronger than the whole, castings were formed both from the hot and cold blast iron (experiments 8, 9, 10, in the one, and 8, 9, in the other). They were all from the same model and ground to the exact size, and the part taken off in the frustums was $\frac{1}{10}$th of the whole height of the triangle. The breaking weights of the whole triangle, in the hot blast iron were 672 and 812 lbs., mean 742 lbs. and of the frustum 728 lbs. In the cold blast iron the whole triangle was broken with 815 lbs., and the frustum with 677. The difference in the transverse strengths of the hot and cold blast Carron irons, No. 2, is very small, the ratio between them being 99 to 100. (See recapitulation at the close of this report.) We may therefore assume their strengths to be the same, and taking an arithmetic mean between all the strengths we have strength of triangle 766 lbs., strength of frustum 702 lbs. The frustum is therefore weaker than the triangle.

It is often asserted by practical men that if the hard skin at the outside of a cast iron bar be removed, its strength, comparatively with its dimensions, will be much reduced; to try this, four bars, $1\frac{1}{4}$ inch square each, were made, two of hot and two of cold blast; they were then planed in the middle to one inch square nearly: their results are in experiments 11 and 12 in Table 1, and 10 and 11 in Table 2. Their strengths were fully equal to those of bars 1 inch square, which were cast with them but not inserted.

It is generally admitted that the strength of a rectangular beam, whose length and breadth are given, is as the square of the depth. To ascertain how far this important law agrees with experiment, castings were formed both in the Carron and

Devon irons; they were 1 inch broad, and had their depths 1, 3, and 5 inches, the distance between the two supports being as usual, 4 feet 6 inches. It is evident then, that if the strength of each of these beams, when reduced to the exact size, be divided by the square of the depth, the quotient should be the same in each case. Hence, taking the mean reduced strength of the 1-inch bars for the first number in each iron, the reduced strength of the 3-inch bars divided by 9 for the second number, and the reduced strength of the 5-inch bars divided by 25 for the third number, we have

In Carron, No. 2, hot blast .	452	427	402
Do. cold blast. .	453	417	414
In Devon Iron, No. 3, hot blast	537	576	617
Do. cold blast	448	377	405
	472	449	459

If we compare the numbers in each line, they differ widely; but taking the mean, they approach nearly to equality. We may therefore admit that the strength is as the square of the depth.

Table III.

Results of Experiments made to ascertain the Transverse Strength of Devon Iron, No. 3.

All the castings were run 5 feet long, as before; they were uniform throughout, and supported on props 4 feet 6 inches asunder. Devon Iron, No. 3, made with *Coal* and a Hot Blast.

Experiment 1. Depth of bar... 1·00 Breadth of do. 1·00			Experiment 2. Depth of bar... 1·01 Breadth of do. 1·01			Experiment 3. Depth of bar... 1·50 Breadth of do. 1·50			Experiment 4. Depth of bar... 3·00 Breadth of do. 1·03 Weight of do. 48 lbs.			Experiment 5. Depth of bar... 4·98 Breadth of do. 1·03 Weight of do. $80\frac{1}{4}$ lbs.			Experiment 6. Uniform beam 5·15 in. deep, with ribs top and bottom, of transverse areas, as $1 : 6\frac{1}{2}$. Weight of beam, 98 lbs.		
Weight in lbs.	Deflection in inches.	Set.	Weight in lbs.	Deflection in inches.	Set.	Weight in lbs.	Deflection in inches.	Set.	Weight in lbs.	Deflection in inches.	Set.	Weight in lbs.	Deflection in inches.	Set.	Weight in lbs.	Deflection in inches.	Set.
112	·20		112	·185		112	·04		896	·068	·002	5402	·089	·002	5867	·05	
168	·30	·002	168	·29		224	·08		1008	·073	·003	5867	·10	·002	6798	·058	
224	·41	·01	224	·40	·007	336	·12		1082	·077	·004	6798	·117		7730	·06	
280	·51		280	·50		448	·17		1306	·094	·004	7730	·135	·008	8196	·07	·002
336	·62	·02	336	·61	·020	560	·22	·005	1530	·108	·005	8662	·153		8662	·074	·004
392	·73	·03	392	·73		672	·26		1754	·125	·008	9593	·17	·015	9593	·08	·004
448	·84	·04	448	·85	·05	784	·31		1978	·147	·010	10524	·19		10646	·093	·008
476	·90		504	·99		896	·36		2202	·162	·012	11950	·22		12751	·108	·01
504	·97		560	1·14		1008	·42		2426	·180	·014	14190	·28		14857	·130	
			574	1·17		1120	·47	·035	2650	·200	·017	15758	broke		16963	·150	·011
			588	broke		1232	·52		2874	·218	·019				19068	·17	·014
						1344	·58		3098	·240	·024				20121	·18	
						1456	·64		3322	·261	·026				21174	·195	
						1568	·71		3546	·286	·029				25817	broke	
						1680	·79		3770	·310	·032						
						1792	·85		3994	·333	·040						
						1904	·96		4218	·360	·047						
						2016	1·05		4442	·388	·055						
						2128	1·16		4666	·420	·067						
						2184	broke		4890	·450	·081						
									5114	·495	·100						
									5338	·530	broke						
Broke in half a minute one inch from the middle.			∴ Ultimate deflection = 1·20.			∴ Ultimate deflection = 1·21.			Broke in about a minute.			∴ Ultimate deflection = ·32.			Broke by tension, or tearing the lower rib asunder.		

Table IV.

Devon Iron, No. 3, made with *Coke* and a Cold Blast. Distance between the supports as before.

Experiment 1. Depth of bar... 1·00; Breadth of do. 1·00

Weight in lbs.	Deflection in inches.	Set.
112	·19	
168	·29	
224	·39	
280	·49	
336	·59	·001
364	·64	·002
392	·68	
420	·73	
448	broke	

∴ Ultimate deflection = ·78.

Experiment 2. Depth of bar... 1·00; Breadth of do. 1·00

Weight in lbs.	Deflection in inches.	Set.
112	·195	
168	·295	
224	·40	
252	·45	·002
280	·50	·005
336	·59	
392	·70	·01
420	·75	
448	·80	

Broke in ½ a minute after the weight 448 lbs. had been put on again.

Experiment 3. Depth of bar... 1·48; Breadth of do. 1·49

Weight in lbs.	Deflection in inches.	Set.
336	·13	
448	·17	
504	·20	·003
560	·22	·005
672	·27	
784	·31	
896	·36	
1008	·41	
1120	·46	·015
1232	·51	
1288	·53	

Broke in half a minute after loading.

Experiment 4. Depth of bar... 1·50; Breadth of do. 1·50

Weight in lbs.	Deflection in inches.	Set.
336	·13	
392	·156	·004
448	·18	·01
560	·23	·01
672	·27	
784	·32	
896	·37	
1008	·42	
1120	·47	·02
1232	·52	
1288	·55	
1344	broke	

∴ Ultimate deflection = ·58.

Experiment 5. Depth of bar... 2·97; Breadth of do. 1·00; Weight of do. 44½ lbs.

Weight in lbs.	Deflection in inches.	Set.
1120	·083	+
1232	·100	·003
1306	·097	
1530	·113	·003
1754	·132	·004
1978	·151	·004
2202	·168	·006
2426	·189	·007
2650	·207	·008
2874	·227	
3098	·248	·01
3322	broke	

∴ Ultimate deflection = ·269.

Experiment 6. Depth of bar... 4·98; Breadth of do. 1·01; Weight of do. 77½ lbs.

Weight in lbs.	Deflection in inches.	Set.
4936	·08	
5402	·089	·005
5867	·097	·007
6333	·105	
6798	·11	
7264	·117	
7730	·127	·01
8662	·138	·011
9593	·157	·012
10152	broke	

∴ Ultimate deflection = ·168.

Experiment 7. Uniform beam 5·13 inches deep, from same model as that in Experiment 6, Hot Blast. Weight of bar, 91½ lbs.

Weight in lbs.	Deflection in inches.	Set.
4936	·058	
5867	·070	
6798	·083	
7264	·090	·002
7730	·096	·004
9593	·120	·007
10646	·135	
12751	·167	·013
14857	·202	·018
16963	·240	·030
19068	·275	·048
21174	·325	·07
22227	broke	

Broke by tension on the bottom rib being torn asunder.

Results of TABLE III. *reduced to those of Bars* 1 *inch broad, and* 1, 1½, 3, *and* 5 *inches deep.*

	Specific gravity.	Breaking weight in lbs. (*b*).	Ultimate deflection in inches (*d*).	Product $b \times d$, or power of resisting impact.	Modulus of elasticity in lbs. for a base of 1 in. square.
Experiment 1st, bar 1 inch deep, 4 feet 6 inches span	7251	504	·97	488·8	22,044,900
Experiment 2nd, bar 1 inch deep, do. do.	......	570	1·21	689·7	22,902,400
Mean	......	537	1·09	589·2	22,473,650
Experiment 3rd, bar 1½ inch deep, do. do.	......	1456	1·21	1761·7	
Experiment 4th, bar 3 inches deep, do. do.	......	5183	·53	2747	
Experiment 5th, bar 5 inches deep, do. do.	......	15422	·32	4935	

Results of TABLE IV. *reduced to those of Bars* 1 *inch broad, and* 1, 1½, 3, *and* 5 *inches deep.*

	Specific gravity.	Breaking weight in lbs. (*b*).	Ultimate deflection in inches (*d*).	Product $b \times d$, or power of resisting impact.	Modulus of elasticity in lbs. for a base of 1 in. square.
Experiment 1st, bar 1 inch deep and 4 feet 6 inches span	7306	448	·78	349·4	23,205,200
Experiment 2nd, bar 1 inch deep, do. do.	7285	448	·80	358·4	22,610,200
Mean	......	448	·79	353·9	22,907,700
Experiment 3rd, bar 1½ inch deep, do. do.	7340	888	·54	479·5	
Experiment 4th, bar 1½ inch deep, do. do.	7251	892	·56	499·5	
Mean	7295	890	·55	489·5	
Experiment 5th, bar 3 inches deep, do. do.	......	3389	·272	921·8	
Experiment 6th, bar 5 inches deep, do. do.	......	10133	·168	1702·3	

The last experiment in both the preceding tables was upon a beam of the best form of section, according to the writer's experiments, (Manchester Memoirs, vol. 5.) the top and bottom rib being nearly in the ratio of the tensile to the compressive forces of the metal, as mentioned above. The intention was to compare the strength of the beam with that of a rectangular one of the same weight, length, and depth. For this purpose the beams were cast uniform throughout, and in comparing the strength of that in the hot blast iron with the mean from the strengths of the two preceding rectangular beams, reduced as above, we find that the breaking weight of these is 19,108 lbs., and the beam of best form was broke with 25,817 lbs. In the cold blast Devon iron the difference in strength is much greater. The rectangular beam, from the mean of the two experiments on the beams 3 inches and 5 inches deep, when reduced as above, gives 11,183 lbs. for the breaking weight, whilst the beam of the best form required 22,227 lbs. to break it.

TABLE V.—Results of Experiments to determine the transverse strength of rectangular bars of iron of the quality No. 1, from the Buffery Iron Works, near Birmingham.

All the specimens were cast 5 feet long, and supported on props 4 feet 6 inches asunder.

Hot Blast Iron.

Experiment 1. Depth of bar .... 1·005; Breadth of do. .... 1·030; Weight of do., 15 lbs. 13 oz.			Experiment 2. Depth of bar .... 1·000; Breadth of do. .... 1·010; Weight of do., 15 lbs. 7 oz.			Experiment 3. Depth of bar .... 1·000; Breadth of do. .... 1·010; Weight of do., 15 lbs. 4 oz.			Experiment 4. Depth of bar .... 2·000; Breadth of do. .... 1·970; Weight of do., 60 lbs. 6 oz.			Experiment 5. Depth of bar .... 2·000; Breadth of do. .... 1·980; Weight of do., 60 lbs.		
Weight in lbs.	Deflection in inches.	Set.	Weight in lbs.	Deflection in inches.	Set.	Weight in lbs.	Deflection in inches.	Set.	Weight in lbs.	Deflection in inches.	Set.	Weight in lbs.	Deflection in inches.	Set.
112	·310	—	112	·315	·018	112	·322	·010	1082	·210	·015	1082	·217	·028
224	·680	·037	224	·660	·045	224	·720	·055	1306	·257	·020	1306	·270	·031
336	1·140	·100	336	1·110	·120	336	1·200	·128	1754	·368	·035	1754	·380	·045
392	1·410	—	392	1·360	·170	392	1·490	·210	2202	·495	·060	2202	·510	·075
448	1·710	·254	441	broke		413	broke		2650	·639	·100	2650	·662	·117
483	broke								2874	·720	·122	2874	broke	
									2930	broke				
∴ Ultimate deflection = 1·840.			∴ Ultimate deflection = 1·530.			∴ Ultimate deflection = 1·570.			∴ Ultimate deflection = ·740.			∴ Ultimate deflection = ·732.		

Results reduced to those of bars 1·000 *and* 2·000 *inch square.*

	Specific gravity.	Breaking weight in lbs. (b).	Ultimate deflection in inches (d).	Product $b \times d$, or power of resisting impact.	Modulus of elasticity in lbs. for a base of 1 in. square.
Experiment 1st, bar 1 inch square, 4 feet 6 inches span	6938	464	1·84	853·76	13603000
Experiment 2nd, bar 1 inch square, do. do.	7050	437	1·53	668·61	13858000
Experiment 3rd, bar 1 inch square, do. do.	7008	409	1·57	642·13	
Mean	6998	436	1·64	721·50	13730500
Experiment 4th, bar 2 inches square, do. do.	......	2975	·740	2201·500	
Experiment 5th, bar 2 inches square, do. do.	......	2903	·732	2124·996	
Mean		2939	·736	2163·248	

TABLE VI.—Results of Experiments on rectangular bars of Buffery Iron, No. 1, continued.

Cold Blast Iron.

Experiment 1.			Experiment 2.			Experiment 3.			Experiment 4.			Experiment 5.		
Depth of bar .... 1·004 Breadth of do. .... ·900 Weight of do., 15 lbs. 3 oz.			Depth of bar .... 1·013 Breadth of do. .... 1·014 Weight of do., 15 lbs. 7 oz.			Depth of bar .... 1·010 Breadth of do. .... 1·025 Weight of do., 15 lbs. 15 oz.			Depth of bar............... 2·00 Breadth of do............. 1·99 Weight of do., 61 lbs.			Depth of bar............... 1·98 Breadth of do. .... 1·98 Weight of do., $60\frac{1}{2}$ lbs.		
Weight in lbs.	Deflection in inches.	Set.	Weight in lbs.	Deflection in inches.	Set.	Weight in lbs.	Deflection in inches.	Set.	Weight in lbs.	Deflection in inches.	Set.	Weight in lbs.	Deflection in inches.	Set.
105	—	·010	105	—	·005	86	—	+	1082	·185	·014	1082	·187	·017
112	·28	·011	112	·278	·008	93	—	·003	1306	·235	·020	1306	·23	·02
224	·612	·050	224	·587	·036	112	·275	·006	1754	·332	·036	1754	·338	·037
336	1·00	·105	336	·953	·083	224	·610	·046	2202	·44	·055	2202	·435	·058
392	1·22	·150	448	1·39	·170	336	1·00	·100	2650	·56	·08	2650	·55	·084
448	1·46	·210	455	broke		392	1·23	·150	2874	·629	·10	2874	·617	·100
490	broke					448	1·49	·217	3042	broke		3098	·69	·123
						483	broke					3322	·774	·15
∴ Ultimate deflection = 1·60.			∴ Ultimate deflection = 1·41.			∴ Ultimate deflection = 1·61.			∴ Ultimate deflection = ·674.			Broke in about a minute after the weight 3322 lbs. had been put on.		

Results reduced to those of bars 1·000 *and* 2·000 *inch square.*

	Specific gravity.	Breaking weight in lbs. (b).	Ultimate deflection in inches (d).	Product $b \times d$, or power of resisting impact.	Modulus of elasticity in lbs. for a base of 1 in. square.
Experiment 1st, bar 1 inch square, 4 feet 6 inches span	7086	491	1·60	785·60	15716100
Experiment 2nd, bar 1 inch square, do. do.	7090	437	1·43	624·91	15046300
Experiment 3rd, bar 1 inch square, do. do.	7061	462	1·63	753·06	
Mean	7079	463	1·55	721·19	15381200
Experiment 4th, bar 2 inches square, do. do.	......	3057	·674	2060·418	
Experiment 5th, bar 2 inches square, do. do.	......	3424	·766	2622·784	
Mean.........	......	3240	·720	2341·601	

General Abstract of transverse strengths.

In the following abstract the transverse strengths of hot and cold blast irons to bear pressure and impact will be given, together with the ratio of these strengths.

The comparison will be made between the results of bars from the same models, taking the reduced results, where such reduction has been made.

Carron Iron No. 2.

	Strength of Irons.			Power to bear impact.		
	Cold Blast Iron.	Hot Blast Iron.	Ratio of strengths. The strength of Cold Blast Iron being represented as 1000.	Cold Blast Iron.	Hot Blast Iron.	Ratio. The power of Cold Blast being represented as 1000.
Results reduced.	492	469	1000 : 953·2	686	677·2	1000 : 987·1
	509	456	1000 : 895·8	711	649·3	1000 : 913·2
	429	465	1000 : 1083·9	493	532·0	1000 : 1079·1
	449	475	1000 : 1057·9	1481	1598·7	1000 : 1079·4
	457	429	1000 : 938·7	2601	2744·2	1000 : 1055·0
	3750	3843	1000 : 1024·8	141	154	1000 : 1092·2
	10362	{10957, 9149} 10053	1000 : 970·1	3391	3087	1000 : 910·3
				530	452	1000 : 852·8
				359	458·6	1000 : 1277·4
		Mean	1000 : 989·1		Mean	1000 : 1005·1
Results not reduced.	266	280	1000 : 1052·6			
	1050	980	1000 : 933·3			
	815	{672, 817} 742	1000 : 910·4			
	677	728	1000 : 1075·0			
		Mean	1000 : 992·8			
		General Mean	1000 : 990·9			

Devon No. 3 Iron.

Cold Blast Iron.	Hot Blast Iron.	Ratio of strengths.	Cold Blast Iron.	Hot Blast Iron.	Ratio.
448	504	1000 : 1125·0	353·9	589·2	1000 : 1664·8
448	570	1000 : 1272·3	489·5	1761·7	1000 : 3598·9
890	1456	1000 : 1635·9	921·8	2747	1000 : 2980·0
			1702·3	4935	1000 : 2899·0
3389	5183	1000 : 1529·3		Mean	1000 : 2785·6
10133	15422	1000 : 1521·9			
	Mean	1000 : 1416·9			

Buffery No. 1 Iron.

Cold Blast Iron.	Hot Blast Iron.	Ratio of strengths.	Cold Blast Iron.	Hot Blast Iron.	Ratio.
491	464	1000 : 945·0	721·19	721·5	1000 : 1000·4
437	437	1000 : 1000·0	2341·6	2163·2	1000 : 923·8
462	409	1000 : 885·7			
3057	2975	1000 : 973·1		Mean	1000 : 962·1
3424	2903	1000 : 850·1			
	Mean	1000 : 930·7			

Having now subjected the irons which are tried in this paper to a variety of strains, and given the results under their proper heads, a summary of the whole will be added, with remarks to show the general bearing upon the question of Hot and Cold Blast Iron.

Recapitulation.

Taking only the means from all the experiments in the present paper, and attaching to each value a number, in a parenthesis, indicative of the quantity of experiments from which it has been derived, we have as below :—

Carron Iron No. 2.

	Cold Blast.	Hot Blast.	Ratio representing Cold Blast by 1000.	
Tensile strength in lbs. per square inch	16683 (2)	13505 (3)	1000 : 809	
Compressive strength in lbs. per inch from castings torn asunder	106375 (3)	108540 (2)	1000 : 1020	
Do. from prisms of various forms	100631 (4)	100738 (2)	1000 : 1001	Mean 997
Do. from cylinders	125403 (13)	121685 (13)	1000 : 970	
Transverse strength from all the experiments	.... (11)	.... (13)	1000 : 991	
Power to resist impact	.... (9)	.... (9)	1000 : 1005	
Transverse strength of bars one inch square in lbs.	476 (3)	463 (3)	1000 : 973	
Ultimate deflection of do. in in.	1·313 (3)	1·337 (3)	1000 : 1018	
Modulus of elasticity in lbs. per square inch	17270500 (2)	16085000 (2)	1000 : 931	
Specific gravity	7066	7046	1000 : 997	

Devon Iron No. 3.

Tensile strength	....	21907 (1)	
Compressive strength	....	145435 (4)	
Transverse ditto from the experiments generally	.... (5)	.... (5)	1000 : 1417
Power to resist impact	.... (4)	.... (4)	1000 : 2786
Transverse strength of bars one inch square	448 (2)	537 (2)	1000 : 1199
Ultimate deflection ditto	·79 (2)	1·09 (2)	1000 : 1380
Modulus of elasticity ditto	22907700 (2)	22473650 (2)	1000 : 981
Specific gravity	7295 (4)	7229 (2)	1000 : 991

Buffery Iron No. 1.

Tensile strength	17466 (1)	13434 (1)	1000 : 769
Compressive ditto	93366 (4)	86397 (4)	1000 : 925
Transverse ditto	.... (5)	.... (5)	1000 : 931
Power to resist impact	.... (2)	.... (2)	1000 : 963
Transverse strength of bars one inch square	463 (3)	436 (3)	1000 : 942
Ultimate deflection ditto	1·55 (3)	1·64 (3)	1000 : 1058
Modulus of elasticity ditto	15381200 (2)	13730500 (2)	1000 : 893
Specific gravity	7079	6998	1000 : 989

Coed-Talon Iron, No. 2.

	Cold Blast.	Hot Blast.	Ratio representing Cold Blast by 1000.
Tensile strength	18855 (2)	16676 (2)	1000 : 884
Compressive do......................	81770 (4)	82739 (4)	1000 : 1012
Specific gravity	6955 (4)	6968 (3)	1000 : 1002
Carron Iron No. 3.			
Tensile strength	14200 (2)	17755 (2)	1000 : 1250
Compressive ditto..................	115442 (4)	133440 (3)	1000 : 1156
Specific gravity	7135 (1)	7056 (1)	1000 : 989

Of the three columns of numbers in the table above, the first is the strength or other quality in the cold blast iron; the second is that in the hot blast; and the third is the ratio of these quantities.

The results in this table contain nearly the whole information relative to the question of hot and cold blast iron that the preceding research affords; and before adverting to them it may be mentioned that it is usual for the makers of cast-iron to divide it, when taken from the furnace, into three classes, called Nos. 1, 2, 3, differing from each other in the appearance and qualities of the material. No. 1 contains the softest and richest irons, those which have the largest crystals; No. 3, the hardest and densest irons, those with the least crystals; and No. 2, irons intermediate between the former two descriptions. Beginning with the No. 1 iron, of which we have a specimen from the Buffery Iron Works, a few miles from Birmingham, we find the cold blast iron somewhat surpassing the hot blast in all the following particulars—direct tensile strength, compressive strength, transverse strength, power to resist impact, modulus of elasticity or stiffness, specific gravity; whilst the only numerical advantage possessed by the hot blast iron is that it bends a little more than the cold blast before it breaks.

In the irons of the quality No. 2 the case seems in some degree different; in these the advantages of the rival kinds seem to be more nearly balanced. They are still, however, rather in favour of the cold blast.

Referring to the No. 2 iron, from the Carron Works in Scotland, we find the tensile, compressive, and transverse strengths, together with the modulus of elasticity and specific gravity, all higher in the cold blast iron than the hot blast, whilst the ultimate deflection and power of sustaining impact are

greater in the hot blast. The cold blast iron is the better, but the difference is very small.

In the iron No. 2, from the Coed-Talon Works in North Wales, the tensile strength is greater in the cold blast than in the hot; but the resistance to compression is higher in the latter than the former, and that is the case with the specific gravity.

So far as my experiments have proceeded, the irons of No. 1 have been deteriorated by the hot blast; those of No. 2 appear also to have been slightly injured by it; whilst the irons of No. 3 seem to have benefited by its mollifying powers. The Carron iron No. 3, hot blast, resists both tension and compression with considerably more energy than that made with the cold blast; and the No. 3 hot blast iron from the Devon Works, in Scotland, is one of the strongest cast-irons I have seen, whilst that made with the cold blast is comparatively weak, though its specific gravity is very high, and higher than in the hot. The extreme hardness of the cold blast Devon iron above prevented many experiments that would otherwise have been made upon it, no tools being hard enough to form the specimens. The difference of strength in the Devon irons is peculiarly striking.

From the evidence here brought forward, it is rendered exceedingly probable that the introduction of a heated blast into the manufacture of cast iron has injured the softer irons, whilst it has frequently mollified and improved those of a harder nature; and considering the small deterioration that the irons of the quality No. 2 have sustained, and the apparent benefit to those of No. 3, together with the great saving effected by the heated blast, there seems good reason for the process becoming as general as it has done.

Additional evidence will be obtained from the experiments in the next paper.

On the Strength and other Properties of Cast Iron obtained from the Hot and Cold Blast. By W. Fairbairn, *Esq.*

The collecting of material for ascertaining the comparative values of iron, made from the hot and cold blast, has been a work of no small labour and expense. The chief difficulties arose from the greater part of the works in this country having only one sort of iron: large quantities of both sorts were obtained; but, excepting those irons experimented upon, none could be found for comparison, nor any on which we could depend for analogous results.

Nearly the whole of the Scotch irons are now prepared by the hot blast; and, with few exceptions, we may consider those of this country and Wales produced under circumstances precisely similar. The great saving effected in the process of smelting by heated air, is in itself a sufficient inducement for its extended application; and in those districts where the iron is not deteriorated, there cannot exist a doubt as to the advantages derivable from its introduction. In confirmation of this opinion, it may be important to know, that one-half or three-fourths of the British ores are now reduced by heated air. In the Staffordshire and Shropshire districts it has become almost universal; and in North and South Wales the old process is rapidly giving way to the more economical application of the hot blast. In Yorkshire it has been tried with indifferent success, first at the Low Moor Iron Works, near Bradford, and more recently at the Milton Works, near Sheffield. The proprietors of the former establishment persevered for some time in the use of the hot blast, but after repeated trials and experiments (part of which are briefly detailed in this Report), they abandoned the process, as injurious to the material, and reconstructed the old apparatus for the cold blast.

I believe at the present moment they use air at the temperature of the atmosphere: it is forced from the blowing cylinder into a dry receiver, and from thence into the furnace. Whether the failure which took place at the Low Moor was owing to some peculiarity in the ores, or from the presence of sulphur in the fuel, I am unable to determine. It is however obvious, that a considerable deterioration of strength was the consequence; and from that cause, and that alone, I am informed, the hot blast was discontinued.

At the Milton Works, the heated air is still in use; and al-

though the iron produced is inferior in strength to that made at the neighbouring works, the Elsicar, where the cold blast is used, it is nevertheless much improved by the introduction of a small proportion of the Ulverstone ores, about 6 per cent., in combination with those found in the district.

Notwithstanding the unfavourable circumstances attending the application of the hot blast in the reduction of the Yorkshire ores, the same results were not obtained in its application to the Scotch iron. In those a deterioration takes place less frequently, as will be seen from the experiments.

Taking a general mean of the experiments in both cases, the difference is not considerable; and, with the exception of the Yorkshire irons, I should consider the results in no way unfavourable to the hot blast: as respects fluidity, appearance, &c., I should rather deem them favourable than otherwise.

Previous to commencing the experiments, it was considered desirable to collect as large an assortment of iron of both kinds as possible; and in order to avoid an improper selection, direct application was made to the iron masters in the first instance, and subsequently numerous samples were received through the medium of persons whose interests were in no way identified with this inquiry.

In this way we kept clear of preconceived opinions, and collected a mass of material of almost every description. Out of nearly one hundred specimens, only six could be found answering the description of hot and cold blast; viz. the Carron, Devon, Buffery, Coed-Talon, and perhaps the Elsicar and Milton.*

The difficulties thus enumerated, and the scarcity of the comparative metals, have of necessity confined our investigations to the above-named irons: they are consequently more limited than we could wish; but, at the same time, of such a nature as, I trust, will lead to important results.

As an account of the greater portion of the irons collected could not be introduced into these Reports, I was nevertheless induced to examine them minutely; and having tested the whole by careful experiment, the results will be found in a distinct form in the sixth volume of the Manchester Memoirs, now in the press.

* Since the above was written, it was deemed expedient to renew the application to the Carron Company for further supplies of their iron, in order to investigate its nature with increased attention, in addition to the experiments of last year. Mr. Hodgkinson expressed a wish to renew his experiments on the tensile forces of this iron, and also to repeat those with sections of the T form, which were found defective in former experiments. For this purpose a second application was made, through Mr. Murray of Glasgow, to the Company, who immediately furnished the necessary samples. Other sorts, the Muirkirk, the Coed-Talon No. 3, including the Carron No. 3 irons, have been obtained, and their results will be given in the present paper.

After the request of the Association, expressed to Mr. Hodgkinson and myself, that an inquiry should be instituted into the comparative merits of iron made from hot and cold blast, nearly ten months elapsed before the necessary materials could be obtained. In fact, the experiments would have been of the most meagre description, for want of samples, but for the friendly cooperation and assistance of Mr. Murray, of the Monkland Iron Works. To that gentleman we are indebted for the whole of the Scotch irons, exclusive of other valuable information relative to the fuel and analysis of the ores; I have therefore great pleasure in thus publicly expressing my acknowledgments.

Before entering upon the experiments, I made application to the greater part of the works from whence iron was received, for information relative to the nature of the ores, fuel, flux, &c.; also for such analyses as the proprietors might be enabled or disposed to furnish, including the temperature of the air used in the process of smelting.

To these inquiries I received replies which, although of great importance in themselves, could not with propriety be introduced into this report.*

During the progress of the investigation, it was found desirable for Mr. Hodgkinson and myself to divide our labours; and in order to examine the different irons with the utmost care, the experiments were classed and apportioned in the manner described in Mr. Hodgkinson's report.

This division was attended with considerable benefit, as it excited a closer investigation of the subject; and the whole of the experiments being made at my works, gave a facility for comparison that could not otherwise be obtained.

* Mr. Murray, of the Monkland Iron Works, has, however, supplied me with the following particulars relative to the Scotch irons, viz. the Carron and Devon irons, which are derived, like most of the Scotch metals, from argillaceous carbonate of iron, and are found in the coal-basins of the country. Some of the poorer ores are found in balls imbedded in argillaceous schistus, and worked or turned out with the coal; but the principal is a seam of black band, at a depth of 15 to 25 fathoms under the splint, or fifth seam of coal, of the Lanarkshire basin. This iron-stone varies from 9 to 15 inches in thickness, and contains from 35 to 40 per cent. of iron. Two-thirds of this ore is generally used to each charge, and one-third of the poorer balls and bands containing from 20 to 25 per cent.—Dr. Colquhoun analyzed the black band ore, which gave

Carbonic acid	35·17	Alumina	0·63
Protoxide of iron	53·03	Peroxide of iron	0·23
Lime	3·33	Calcareous or bituminous matter	3·03
Magnesia	1·77	Moisture and loss	1·41
Silica	1·40		100·000

The specific gravity of this ore is 3·0553, colour close brown. The ore contains an intermixture of imbedded bivalve shells.

In describing the following experiments, I will first give the tables and results on the transverse or more usually investigated species of strain, where the experiment was made without loss of time, and which may be considered a continuation of the same class of experiments by Mr. Hodgkinson. We shall then proceed to experiments on the Coed-Talon bars, in relation to time or indefinite strain. Afterwards we shall exhibit others on the effects of temperature; and finally close with a general summary of results.

Before presenting the experiments in their tabulated forms, it may be necessary to supply a brief description of each class, in order to show the methods adopted, and how the results were obtained.—For this purpose, a number of models were prepared, to be 1 inch and 1½ inches square; and the metals, both hot and cold blast, were run into the form of those models. But as there is generally a slight deviation in the size of the casting from that of the model, the dimensions of the bars were accurately measured at the place of fracture, and the results reduced (when practicable) by calculation to what they would have been if cast to the exact size of the model. This was done to ensure more accurate comparisons in the strength and other mechanical properties of the bars. The mode of reduction is described in the preceding report.

In addition to the methods herein adopted to determine the strength, tenacity, and value of the different irons made from hot and cold blast, I conceived it necessary to institute a series of microscopic observations; to examine with great minuteness the appearance of the fracture, and by magnifying the crystals, to elucidate such visible indications of the fluidity, strength, and ductility of the irons, as would distinguish the qualities of the different numbers known in commerce by the name of No. 1, 2, and 3 iron.

I also pursued in other respects a close and minute examination of the different specimens of hot and cold blast iron, and by turning, filing, grinding, &c., endeavoured to discover their properties in relation to each other, and their adaptation to the arts.

As the Carron No. 2 irons, hot and cold blast, were among the first we obtained, I have, in the description of the fractures attached to each table of experiments, made the Carron No. 2 cold blast iron the basis of comparison. It may therefore be proper to give here the following short description of it.

This iron, when viewed with a microscope, presents a dull grey colour, finely granulated, with an appearance of greater porosity in the centre than round the extreme edges of the fracture. It is a free-working iron, easily cut with the turning tool, but indicates stiffness under the file.

TABLE I.—North Wales Iron.—Coed-Talon No. 2 Pig-Iron, Cold Blast.

EXPERIMENT 1.			EXPERIMENT 2.			EXPERIMENT 3.			EXPERIMENT 4.			EXPERIMENT 5.		
Depth of bar, 1·042 Breadth of do. 1·021 Distance between supports, 4 ft. 6 in. Weight of bar, 5 ft. long, 16¼ lbs.			Depth of bar, 1·061 Breadth of do. 1·018 Distance between supports, 4 ft. 6 in. Weight of bar, 5 ft. long, 16 lbs. 2 oz.			Depth of bar, 1·04 Breadth of do. 1·02 Distance between supports, 4 ft. 6 in. Weight of bar, 5 ft. long, 15 lbs. 9 oz.			Depth of bar, 1·076 Breadth of do. 1·04 Distance between supports, 2 ft. 3 in.			Depth of bar, 1·062 Breadth of do. 1·009 Distance between supports, 2 ft. 3 in.		
Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.
28	·057	...	28	·06	...	28	·072	...	112	·028	...	112	·030	...
56	·115	+	56	·122	+	56	·125	+	224	·060	...	224	·064	+
126	·299	·015	126	·297	·018	112	·269	·011	336	·092	+	336	·096	·005
154	·37	·023	154	·37	·027	168	·420	·024	448	·125	·006	448	·134	·007
182	·451	·032	182	·452	·035	224	·584	·042	560	·162	·008	560	·172	·010
238	·615	·06	238	·618	·059	280	·748	·064	672	·203	·010	672	·215	·014
294	·8	·08	294	·797	·083	336	·924	·085	784	·242	·016	784	·258	·020
350	·993	·115	350	·989	·114	392	1·105	·123	896	·290	·025	896	·308	·028
406	1·21	·162	406	1·202	·16	448	1·315	·185	952	·316		952	broke	
434	1·332	·195	434	1·32	·19	462	broke		1008	broke				
448	broke		448	1·386										
			462	broke										
∴ Ultimate deflection, = 1·394. Broke 1¾ inch from the centre.			∴ Ultimate deflection, = 1·452. Broke at the centre.			∴ Ultimate deflection, = 1·364. Broke ½ an inch from the centre.			∴ Ultimate deflection, = ·341. Broke 1⅜ inch from the centre.			∴ Ultimate deflection, = ·332. Broke ½ an inch from the centre.		

The microscopic appearance of this iron is a deeper grey colour than is exhibited in the Carron No. 2 cold blast; it is also more open than it is in the centre of the bar, with a diminution of the crystals as they approach the exterior skin. It is less ductile than the hot blast, and inferior to it in the power of resisting impact.

Results reduced to those of bars 1·00 *inch square.*

	Specific gravity.	Modulus of elasticity in lbs. per square inch.	Breaking weight (*b*).	Ultimate deflection (*d*).	Product *b* × *d*, or power of resisting impact.
Experiment 1st, bar 4 ft. 6 in. between supports.....	6·951 6·916	14680000	404·2	1·453	587·3
Experiment 2nd, bar 4 ft. 6 in. between supports.....	6·916	13947000	403·1	1·540	620·7
Experiment 3rd, bar 4 ft. 6 in. between supports.....	7·038	14285000	418·8	1·419	594·2
Mean...	6·955	14304000	408·7	1·470	600·7
Experiment 4th, bar 2 ft. 3 in. between supports.....	....	....	837·2	·367	307·2
Experiment 5th, bar 2 ft. 3 in. between supports.....	....	....	836·6	·353	295·3
Mean...	....	....	836·9	·360	296·2

TABLE II.

North Wales Iron.—Coed-Talon No. 2 Pig-Iron, Hot Blast.

Experiment 1.			Experiment 2.			Experiment 3.			Experiment 4.		
Depth of bar, 1·071 Breadth of do. 1·000 Distance between supports, 4 ft. 6 in. Weight of bar 5 ft. long, 15¾ lbs.			Depth of bar, 1·057 Breadth of do. 1·010 Distance between supports, 4 ft. 6 in. Weight of bar, 5 ft. long, 16 lbs.			Depth of bar, 1·044 Breadth of do. ·994 Distance between supports, 2 ft. 3 in.			Depth of bar, 1·065 Breadth of do. 1·002 Distance between supports, 2 ft. 3 in.		
Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.
28	·065	...	28	·071	...	112	·031	...	112	·030	...
56	·130	·005	56	·130	·005	224	·070	...	224	·066	...
126	·325	·025	126	·329	·030	336	·109	+	336	·103	·005
182	·503	·052	182	·507	·056	448	·152	·007	448	·144	·007
238	·700	·085	238	·698	·089	560	·200	·012	560	·188	·011
294	·910	·120	294	·910	·124	672	·251	·020	672	·238	·019
350	1·149	·170	350	1·153	·184	784	·307	·030	784	·290	·028
406	1·420	·245	406	1·435	·265	840	·343		896	·355	·045
434	1·570	·295	462	1·764	·370	896	broke		952	·390	
448	1·654		469	broke					980	broke	
462	broke										
∴ Ultimate deflection = 1·738. Broke ¾ of an inch from the centre.			∴ Ultimate deflection = 1·808. Broke ½ an inch from the centre.			∴ Ultimate deflection = ·375. Broke at the centre.			∴ Ultimate deflection = ·407. Broke ⅜ of an inch from the centre.		

In this iron the crystallization is more perfect, when contrasted with the cold blast from the same ore; it presents larger granules than it, accompanied with more lustre over the whole surface of the fracture. It is a free, kindly-working iron; easily cut with the chisel, and files with a sense of adhesion to that instrument.

Results reduced to those of bars 1·00 *inch square.*

	Specific gravity.	Modulus of elasticity in lbs. per square inch.	Breaking weight (b).	Ultimate deflection (d).	Product $b \times d$, or power of resisting impact.
Experiment 1st, bar 4 ft. 6 in. between supports	6·970 6·956	15810000	402·8	1·861	749·6
Experiment 2nd, bar 4 ft. 6 in. between supports	6·977	12835000	415·6	1·911	794·2
Mean...	6·968	14322500	409·2	1·882	771·9
Experiment 3rd, bar 2 ft. 3 in. between supports	....	....	835·5	·392	327·5
Experiment 4th, bar 2 ft. 3 in. between supports	....	....	862·3	·434	374·2
Mean...	....	....	848·9	·413	350·8

Comparative results of Coed-Talon Iron No. 2.

Distance between supports 4 ft. 6 in. and 2 ft. 3 in.

Strength of Cold Blast Iron.		Strength of Hot Blast Iron.		Ratio of strengths.
404·2 403·1 418·8	Mean 408·7	402·8 415·6	Mean 409·2	1000 : 1001
837·2 836·6	Mean 836·9	835·5 862·3	Mean 848·9	1000 : 1014
Mean ratio of strengths, 1000 : 1007				

Results of products, and ratio to resist impact.

Product of strength by ultimate deflection in Cold Blast Iron.		Product of strength by ultimate deflection in Hot Blast Iron.		Ratio of products, or of power to resist impact.
587·3 620·7 594·2	Mean 600·7	749·6 794·2	Mean 771·9	1000 : 1285
307·2 295·3	Mean 296·2	327·5 374·2	Mean 350·8	1000 : 1184
Mean ratio of powers to sustain impact, 1000 : 1234				

Modulus of elasticity in lbs. for a base of an inch square.

Cold Blast Iron......	14680000
Do......................	13947000
Mean...	14313500
Hot Blast Iron	15810000
Do.......................	12835000
Mean...	14322500

Note.—The modulus of elasticity was taken in this, as well as in other cases, from the 4 ft. 6 in. bars, and from the deflection caused by 112 lbs.

Table III.

North Wales Iron.—Coed-Talon No. 3 Iron, Cold Blast.

Experiment 1.			Experiment 2.			Experiment 3.			Experiment 4.		
Depth of bar, ·996 Breadth of do. 1·005 Distance between supports, 4 ft. 6 in.			Depth of bar, 1·035 Breadth of do. 1·017 Distance between supports, 4 ft. 6 in.			Depth of bar, ·996 Breadth of do. 1·015 Distance between supports, 2 ft. 3 in.			Depth of bar, 1·035 Breadth of do. 1·017 Distance between supports, 2 ft. 3 in.		
Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.
28	·067	...	28	·060	...	112	·030	...	112	·031	...
56	·131	+	56	·117	+	224	·068	...	224	·060	...
112	·257	·010	112	·231	·012	336	·102	+	336	·092	+
168	·400	·018	168	·357	·023	448	·140	+	448	·122	·005
224	·542	·030	224	·491	·036	560	·178	·006	560	·156	·007
280	·695	·047	280	·623	·050	672	·217	·008	672	·189	·009
336	·850	·064	336	·762	·069	784	·256	·012	784	·221	·011
392	1·022	·090	392	·910	·089	896	·300	·020	896	·257	·017
448	1·204	·121	448	1·070	·112	1008	·349	·031	1008	·300	·022
504	1·400	·164	504	1·238	·148	1064	·377	...	1120	·340	·031
532	1·520		560	1·425	·191	1120	·408	·045	1176	broke	
560	broke					1176	·439				
						1204	broke				
∴ Ultimate deflection = 1·617. Broke at ¾ of an in. from the centre.			Broke with the weight, 560 lbs., when put on again.			∴ Ultimate deflection = ·453. Broke at the centre.			∴ Ultimate deflection = ·359. Broke at the centre.		

On comparing the Coed-Talon No. 2, cold blast, with the No. 3 cold blast iron, it will be found that the strength and also the power to resist impact is decidedly in favour of the last iron; in the first instance the proportions are as 537·8 to 408·7, in the latter, 831·2 to 600·7, being a ratio of nearly 24 per cent. in favour of the No. 3 iron.

The colour of this iron is a dull grey, with considerable uniformity in its crystalline texture. It is a stiff iron, rather difficult to cut, and accompanied with a hard sensation under the file.

Results reduced to those of bars 1·000 *inch square.*

	Specific gravity.	Modulus of elasticity in lbs. per square inch.	Breaking weight (b).	Ultimate deflection in inches (d).	Product $b \times d$, or power of resisting impact.
Experiment 1st, bar 4 ft. 6 in. between supports ...	7265	17276800	561·7	1·610	904·3
Experiment 2nd, bar 4 ft. 6 in. between supports ...	7124	16927200	514·0	1·475	758·1
Mean...	7194	17102000	537·8	1·542	831·2
Experiment 3rd, bar 2 ft. 3 in. between supports ...	......	......	1195·7	·4512	539·5
Experiment 4th, bar 2 ft. 3 in. between supports ...	......	......	1079·0	·3715	401·0
Mean...	......	......	1137·3	·4113	470·2

Table IV.

North Wales Iron.—Coed-Talon No. 3 Iron, Hot Blast.

Experiment 1. Depth of bar, 1·002 Breadth of do. 1·005 Distance between supports, 4 ft. 6 in.			Experiment 2. Depth of bar, 1·011 Breadth of do. 1·002 Distance between supports, 4 ft. 6 in.			Experiment 3. Depth of bar, 1·015 Breadth of do. 1·015 Distance between supports, 2 ft. 3 in.			Experiment 4. Depth of bar, 1·017 Breadth of do. 1·005 Distance between supports, 2 ft. 3 in.		
Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.
28	·078	+	28	·071	...	112	·037	...	112	·035	...
56	·150	·007	56	·143	+	224	·073	...	224	·070	...
112	·296	·012	112	·290	·011	336	·109	+	336	·108	...
168	·458	·022	168	·450	·026	448	·147	·005	448	·146	+
224	·621	·038	224	·611	·041	560	·182	·006	560	·183	·007
280	·793	·054	280	·780	·060	672	·221	·008	672	·220	·009
336	·978	·074	336	·957	·080	784	·260	·011	784	·261	·011
392	1·170	·100	392	1·142	·103	896	·302	·017	896	·304	·018
448	1·380	·134	448	1·340	·138	1008	·349	·022	952	·328	...
476	1·488		476	1·450		1064	·378		1008	·352	·025
504	broke		504	broke		1092	broke		1064	·380	
									1120	broke	
∴ Ultimate deflection = 1·588. Broke ¾ of an inch from the centre.			∴ Ultimate deflection = 1·547. Broke ½ an in. from the centre.			∴ Ultimate deflection = ·390. Broke ¾ of an inch from the centre.			∴ Ultimate deflection = ·404. Broke 1 inch from the centre.		

The Coed-Talon No. 3, hot blast, is a much clearer iron, with larger crystals than the cold blast, No. 3. It presents a more varied appearance in its crystalline form, with the usual porosity in the centre of the fracture. The colour is more brilliant than that of the last-mentioned iron. This is in many respects similar to the Carron No. 2, cold blast. It is reduced by the file and chisel with more ease than the iron last examined.

Results reduced to those of bars 1·000 *inch square.*

	Specific gravity.	Modulus of elasticity in lbs. per square inch.	Breaking weight (b).	Ultimate deflection (d).	Product $b \times d$, or power of resisting impact.
Experiment 1st, bar 4 ft. 6 in. between supports ...	6992	14732600	499·5	1·591	794·7
Experiment 2nd, bar 4 ft. 6 in. between supports ...	6967 6952	14683200	492·1	1·564	769·7
Mean...	6970	14707900	495·8	1·577	782·2
Experiment 3rd, bar 2 ft. 3 in. between supports ...	......	......	1044·0	·3958	413·2
Experiment 4th, bar 2 ft. 3 in. between supports ...	......	......	1077·5	·4108	442·7
Mean...	......	......	1060·7	·4033	427·9

Comparative results of Coed-Talon No. 3.

Distance between supports, 4 ft. 6 in. and 2 ft. 3 in.

Strength of Cold Blast Iron.	Strength of Hot Blast Iron.	Ratio of strengths.
561·7, 514·0 } 537·8	499·5, 492·1 } 495·8	1000 : 922
1195·7, 1079·0 } 1137·3	1044·0, 1077·5 } 1060·7	1000 : 932
	Mean ratio of strengths......	1000 : 927

Results of products and ratio to resist impact.

Product of strength by ultimate deflection in Cold Blast Iron.	Product of strength by ultimate deflection in Hot Blast Iron.	Ratio of products, or of power to resist impact.
904·3, 758·1 } 831·2	794·7, 769·7 } 782·2	1000 : 941
539·5, 401·0 } 470·2	413·2, 442·7 } 427·9	1000 : 910
	Mean ratio of powers to sustain impact	1000 : 925

Modulus of elasticity in lbs. for a base of an inch square.

Cold Blast Iron......	17276800
Ditto	16927200
Mean	17102000
Hot Blast Iron	14732600
Ditto	14683200
Mean	14707900

If we carefully examine the different experiments in these and the preceding tables, it will appear obvious that the hot blast is in every instance the weaker iron, and whether it is viewed in the long or short specimens, the same marked difference in strength is apparent. It is also clear that the No. 3 hot blast is an iron of greater power than the second quality made by hot blast from the same ore. On contrasting the tables, it will be found that the No. 3 iron exceeds the No. 2 in its power to resist a transverse strain nearly one-fifth, and considerably more in its resisting power to sustain impact, this being in the ratio of 1000 to 766.

I have pointed out the defect of the No. 2 iron, not so much for comparison between the hot and cold blast, as from a desire to show the difference which in general exists between the two qualities. In preparing castings for the purpose of supporting great weights, it will be necessary to have reference to the No. 3 iron, as the best adapted for the purpose; it will be found safer than the richer sorts, and should therefore form a considerable part of the mixtures of these descriptions.

The ratio of difference between the hot and cold blast Coed-Talon No. 3, and the Coed-Talon No. 2, is considerable. In the No. 2 we have the hot blast in the transverse strain a mere fraction stronger, and its power to sustain impact as 1000 to 1234. On the other hand, the No. 3 cold blast stands prominently forward in the ratio of 1000 to 927 for the transverse strength, and 1000 to 925 for the resistance to impact. I offer no opinion as to the cause of these discrepancies; they are correctly given in the experiments, and I must leave the reader to draw his own conclusions.

Tab. V.—English Iron.—Elsicar No. 1 Pig Iron, Cold Blast.

Experiment 1.			Experiment 2.			Experiment 3.			Experiment 4.		
Depth of bar, 1·033 Breadth of do. 1·025 Distance between supports, 4 ft. 6 in. Weight of bar 5 ft. long, 15½ lbs.			Depth of bar, 1·042 Breadth of do. 1·030 Distance between supports, 4 ft. 6 in. Weight of bar 5 ft. long, 15¾ lbs.			Depth of bar, 1·023 Breadth of do. 1·006 Distance between supports 2 ft. 3 in.			Depth of bar, 1·016 Breadth of do. ·990 Distance between supports 2 ft. 3 in.		
Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.
56	·151	...	56	·129	...	112	·030	...	112	·032	...
112	·291	·030	112	·260	·010	224	·062	...	224	·066	+
168	·444	·048	168	·410	·029	336	·095	+	336	·101	·005
224	·611	·064	224	·571	·044	448	·132	·005	448	·141	·007
280	·782	·087	280	·740	·063	560	·170	·008	560	·181	·010
336	·979	·114	336	·918	·090	672	·215	·011	672	·229	·018
392	1·185	·148	392	1·112	·122	784	·260	·017	784	·276	·022
448	1·390	·190	448	1·320	·161	896	·310	·025	896	·330	·030
476	broke		476	broke		952	broke		952	·355	
									1008	broke	
∴ Ultimate deflection = 1·496. Broke 1 inch from the centre.			∴ Ultimate deflection = 1·424. Broke at the centre.			∴ Ultimate deflection = ·334. Broke ¾ of an inch from the centre.			∴ Ultimate deflection = ·381. Broke ⅛ of an inch from the centre.		

It must be observed that the Elsicar is entirely cold blast iron, and is here compared with the Milton hot blast. Both irons are from the same ores, and are generally obtained under the same circumstances. In their relative properties there are, however, some slight discrepancies, arising from an admixture of 5 per cent. of Cumberland ironstone, introduced into the Milton iron during the process. The Elsicar is blown from coke, with cold blast, whilst the Milton is produced from 5 parts coal and 1 part coke, with hot blast.

This iron has a vitrified and glutinous appearance over the entire section of the fracture; there is great uniformity,—the crystals being nearly the same in the centre as those next the outer skin of the bar. It has a grey colour, intermixed with blue. Its working properties are of the first order, the action of filing being accompanied by a soft adhesive sound.

Results reduced to those of bars 1·00 *inch square.*

	Specific gravity.	Modulus of elasticity in lbs. per square inch.	Breaking weight (b).	Ultimate deflection in inches (d).	Product $b \times d$, or power of resisting impact.
Experiment 1st, bar 4 ft. 6 in. between supports...	7·056 7·017	13410000	435·2	1·546	672·8
Experiment 2nd, bar 4 ft. 6 in. between supports ...	7·017	14552000	425·6	1·484	631·6
Mean ...	7·030	13981000	430·4	1·515	652·2
Experiment 3rd, bar 2 ft. 3 in. between supports ...	......	......	904·2	·342	309·2
Experiment 4th, bar 2 ft. 3 in. between supports ...	......	......	986·3	·387	381·7
Mean ...	......	......	945·2	·364	345·4

Tab. VI.—English Irons.—Milton, No. 1 Pig Iron, Hot Blast—Yorkshire.

Experiment 1.			Experiment 2.			Experiment 3.			Experiment 4.		
Depth of bar, 1·064 Breadth of do. 1·064 Distance between supports, 4 ft. 6 in. Weight of bar 5 ft. long, 16 lb. 9 oz.			Depth of bar, 1·058 Breadth of do. 1·020 Distance between supports, 4 ft. 6 in. Weight of bar 5 ft. long, 16 lb. 8 oz.			Depth of bar, 1·090 Breadth of do. 1·047 Distance between supports, 2 ft. 3 in.			Depth of bar, 1·067 Breadth of do. 1·040 Distance between supports, 2 ft. 3 in.		
Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.
42	·103	+	42	·103	+	112	·033	...	112	·033	...
112	·294	·010	112	·298	·006	224	·066	+	224	·070	+
182	·499	·038	182	·518	·033	336	·103	·004	336	·110	·004
238	·685	·065	238	·710	·056	448	·143	·007	448	·153	·006
294	·892	·094	294	·922	·090	560	·186	·009	560	·200	·009
350	1·126	·139	350	1·160	·135	672	·236	·015	672	·250	·016
406	1·382	broke	406	1·430	·209	784	·286	·024	784	·306	·025
			420	broke		896	·350	·038	896	·372	·041
						952	broke		924	broke	
Broke $\frac{3}{8}$ of an inch from the centre.			∴ Ultimate deflection = 1·492. Broke $1\frac{1}{4}$ inch from the centre.			∴ Ultimate deflection = ·379. Broke at the centre			∴ Ultimate deflection = ·388. Broke $\frac{1}{4}$ of an inch from the centre.		

The general appearance of this iron is the usual central porosity of crystallization, which no doubt takes place in consequence of a greater degree of rapidity in the cooling on the outside than within. In the larger descriptions of castings these marks are particularly observable, as the interior mass retains its fluidity for some time after the exterior has assumed the solid form: the phenomena of crystallization are therefore completed under different influences, and hence arises the great and prominent difference which exists in the granulated surface of a large fracture. The working powers of the Milton iron are much akin to the Carron No. 2, cold blast: it possesses less lustre than the Elsicar, but has greater fluidity than appearances would indicate.

Results reduced to those of bars 1·00 *inch square.*

	Specific gravity.	Modulus of elasticity in lbs. per square inch.	Breaking weight (b).	Ultimate deflection in inches (d).	Product $b \times d$, or power of resisting impact.
Experiment 1st, bar 4 ft. 6 in. between supports ...	7·016 6·977	11701000	337·1	1·471	495·8
Experiment 2nd, bar 4 ft. 6 in. between supports ...	6·936	12248000	367·9	1·579	580·9
Mean ...	6·976	11974500	352·5	1·525	538·3
Experiment 3rd, bar 2 ft. 3 in. between supports ...	......	......	765·3	·413	316·0
Experiment 4th, bar 2 ft. 3 in. between supports ...	......	......	780·4	·414	323·0
Mean ...	......	......	772·8	·413	319·5

Comparative results of Elsicar Cold Blast Iron, No. 1, *and Milton Hot Blast, No.* 1.

Distance between supports 4 ft. 6 in.

Elsicar. Strength of the Cold Blast Iron.		Milton. Strength of the Hot Blast Iron.		Ratio of the Strengths.
	Mean.		Mean.	
435·2 425·6	430·4	337·1 367·9	352·5	1000 : 819
904·2 986·3	945·2	765·3 780·4	772·8	1000 : 818
Mean ratio of strengths				1000 : 818

The products, and ratio to resist impact.

Product of strength by ultimate deflection in Cold Blast Iron.		Product of strength by ultimate deflection in Hot Blast Iron.		Ratio of products, or of power to resist impact.
	Mean.		Mean.	
672·8 631·6	652·2	495·8 580·9	538·3	1000 : 825
309·2 381·7	345·4	316·0 323·0	319·5	1000 : 925
Mean ratio of powers to sustain impact				1000 : 875

Modulus of elasticity in lbs. for a base of an inch square.

Elsicar Iron	(Cold Blast)	13410000
Ditto	ditto	14552000
	Mean	13981000
Milton Iron	(Hot Blast)	11701000
Ditto	ditto	12248000
	Mean	11974500

The Elsicar and Milton being the only Yorkshire irons obtained answering to the description of hot and cold blast, it may be proper, in this part of my report, to state that I have been favoured with a series of experiments made at the Low Moor Works, near Bradford, by Mr. Dawson, one of the proprietors. In the year 1830 the hot blast was tried in the reduction of the ores of the Bradford district. A number of bars, 1 inch square, were cast from iron produced in the cold blast furnace of 1829, and a similar number of bars were cast, of the same dimensions, and from the same model and furnace, with hot blast, in 1830. Each of the bars was broken with weights

placed on the centre, and supported on beams or bearers 3 feet asunder. The results are below :

Mean breaking weight of the Cold Blast bars	947	lbs.
Mean ditto ditto Hot Blast bars	787	,,
Difference in favour of Cold Blast	160	

being as 94 to 78 in the ratio of 1000 to 831, or nearly the same in favour of the cold blast as exhibited in the preceding tables.

It appears somewhat remarkable, that the same, or nearly the same, results should be obtained in my experiments of 1836, on the Elsicar and Milton irons, as were elicited in the experiments at the Low Moor in 1830. In both instances there is an obvious defect in the strengths of the iron made by the hot blast; and, judging from the difference in the deflections between the Elsicar and the Milton, I should consider the hot blast more *tender* than the Elsicar, and less worthy of trust than it when submitted to forcible strain under vibratory action; the power to sustain impact being in favour of the former as 1000 to 875. Before closing these observations, I would venture to mention the striking anomaly that exists between the Yorkshire ores and those of other districts when operated upon by the hot blast. From the experiments generally, such a marked difference does not exist in the strength of other irons as are herein portrayed in those of Yorkshire. Some peculiar and probably unknown affinity in the minerals may be brought into action by the heated air, otherwise, I confess, I cannot perceive any just reason for such a change. The mere heating of atmospheric air to 600° or 700° before it enters the furnace, should not, in my opinion, differ so considerably from the same air heated in the furnace. I hope the results of these experiments will induce Dr. Faraday, Dr. Thompson, or some other eminent chemist, to inquire further into this subject, and, by correct analysis, to ascertain the cause of differences which at the present moment appear anything but satisfactory.

TAB. VII.—Scotch Iron.—Carron No. 3 Pig Iron, Cold Blast.

EXPERIMENT 1.			EXPERIMENT 2.			EXPERIMENT 3.			EXPERIMENT 4.			EXPERIMENT 5.		
Depth of bar, 1·020 Breadth of do. 1·010 Distance between supports, 4 ft. 6 in.			Depth of bar, ·997 Breadth of do. 1·001 Distance between supports, 4 ft. 6 in.			Depth of bar, ·995 Breadth of do. 1·005 Distance between supports, 4 ft. 6 in.			Depth of bar, 1·024 Breadth of do. 1·000 Distance between supports, 2 ft. 3 in.			Depth of bar, 1·008 Breadth of do. ·999 Distance between supports, 2 ft. 3 in.		
Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.
28	·068	...	28	·071	+	28	·070	+	112	·032	...	112	·033	...
56	·129	+	56	·140	·007	56	·138	·007	224	·067	+	224	·071	+
112	·253	·010	112	·278	·013	112	·270	·011	336	·100	+	336	·110	+
168	·401	·020	168	·430	·027	168	·422	·025	448	·137	·006	448	·149	·007
224	·552	·038	224	·590	·046	224	·587	·046	560	·177	·009	560	·189	·010
280	·718	·061	280	·755	·069	280	·749	·067	672	·215	·014	672	·233	·017
336	·890	·090	336	·946	·098	336	·928	·095	784	·258	·022	784	·280	·023
392	1·079	·120	392	1·142	·136	392	1·122	·132	896	broke		896	·337	·037
448	1·281	·169	420	1·249		420	1·223					952	broke	
469	broke		434	broke		448	broke							
∴ Ultimate deflection = 1·351. Broke 1 inch from the centre.			∴ Ultimate deflection = 1·297. Broke $\frac{3}{8}$ of an inch from the centre.			∴ Ultimate deflection = 1·315. Broke $\frac{3}{8}$ of an inch from the centre.			∴ Ultimate deflection = ·297. Broke $1\frac{1}{4}$ of an inch from the centre.			∴ Ultimate deflection = ·360. Broke $\frac{1}{2}$ an inch from the centre.		

Carron No. 3, cold blast, indicates (when viewed with a magnifier) an exceedingly close texture, with a rich sparkling grey colour. For No. 3 iron, it possesses more than usual softness, and yields freely either to the chisel or file. I should consider it in no way inferior to most No. 2 irons in relation to its power of being worked.

Results reduced to those of bars 1·00 *inch square.*

	Specific gravity.	Modulus of elasticity in lbs. per square inch.	Breaking weight (b).	Ultimate deflection (d).	Product $b \times d$ or power of resisting impact.
Experiment 1st, bar 4 ft. 6 in. between supports	7054	16259100	446·3	1·410	629·3
Experiment 2nd, bar 4 ft. 6 in. between supports	7135	15987300	436·2	1·293	564·0
Experiment 3rd, bar 4 ft. 6 in. between supports	......	16494500	450·2	1·307	588·4
Mean	7094	16246966	444·2	1·336	593·9
Experiment 4th, bar 2 ft. 3 in. between supports	......	......	854·5	·3041	259·9
Experiment 5th, bar 2 ft. 3 in. between supports	......	......	937·9	·3629	340·3
Mean	......	......	896·2	·3335	300·1

TABLE VIII.—Scotch Iron.—Carron No. 3 Pig Iron, Hot Blast.

Experiment 1.			Experiment 2.			Experiment 3.			Experiment 4.			Experiment 5.		
Depth of bar, ·996 Breadth of do. 1·002 Distance between supports, 4 ft. 6 in.			Depth of bar, 1·006 Breadth of do. 1·015 Distance between supports, 4 ft. 6 in.			Depth of bar, ·989 Breadth of do. 1·001 Distance between supports, 4 ft. 6 in.			Depth of bar, 1·002 Breadth of do. 1·002 Distance between supports, 2 ft. 3 in.			Depth of bar, ·993 Breadth of do. ·998 Distance between supports, 2 ft. 3 in.		
Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.
28	·068	...	28	·067	...	28	·069	...	112	·032	...	112	·034	...
56	·128	+	56	·126	...	56	·132	+	224	·061	...	224	·069	...
112	·250	·006	112	·241	·006	112	·255	·005	336	·097	...	336	·100	...
168	·378	·010	168	·371	.011	168	·391	·013	448	·128	...	448	·137	+
224	·519	·020	224	·510	·020	224	·532	·023	560	·161	+	560	·172	·006
280	·662	·036	280	·647	·033	280	·681	·037	672	·198	·006	672	·208	·009
336	·809	·052	336	·789	·049	336	·831	·055	784	·232	·010	784	·244	·013
392	·974	·077	392	·941	·070	392	1·000	·079	896	·273	·016	896	·290	·019
448	1·142	·106	448	1·104	·093	448	1·174	·110	952	·293	...	952	·312	
476	1·230		504	1·276	·129	476	1·270		1008	·318	·022	1008	broke	
504	broke		532	1·377		504	broke		1064	·340				
			553	broke					1120	broke				
∴ Ultimate deflection = 1·312. Broke $\frac{1}{4}$ of an inch from the centre.			∴ Ultimate deflection = 1·440. Broke $\frac{3}{8}$ of an inch from the centre.			∴ Ultimate deflection = 1·356. Broke at the centre.			∴ Ultimate deflection = ·362. Broke $\frac{1}{2}$ an inch from the centre.			∴ Ultimate deflection = ·332. Broke $\frac{1}{4}$ of an inch from the centre.		

Carron No. 3, hot blast, is a harder iron, with less lustre than its predecessor the cold blast; it is also worked with greater difficulty, and produces a harsh, sonorous sound under the file. It is an iron well adapted for mixing, and of value in heavy castings when used in conjunction with some of the best Welsh irons.

Results reduced to those of bars 1·00 *inch square.*

	Specific gravity.	Modulus of elasticity in lbs. per square inch.	Breaking weight (b).	Ultimate deflection (d).	Product $b \times d$ or power of resisting impact.
Experiment 1st, bar 4 ft. 6 in. between supports	7056	17813700	507·0	1·307	662·6
Experiment 2nd, bar 4 ft. 6 in. between supports	7056	17949900	538·3	1·448	779·5
Experiment 3rd, bar 4 ft. 6 in. between supports	......	17855700	514·7	1·341	690·2
Mean	7056	17873100	520·0	1·365	710·7
Experiment 4th, bar 2 ft. 3 in. between supports	......	......	1113·3	·3627	403·8
Experiment 5th, bar 2 ft. 3 in. between supports	......	......	1024·0	·3297	337·6
Mean	......	......	1068·6	·3462	370·7

Comparative Results of Carron Iron No. 3.

Distance between supports 4 ft. 6 in. and 2 ft. 3 in.

Strength of Cold Blast Iron.	Strength of Hot Blast Iron.	Ratio of strengths.
446·3 436·2 450·2 } 444·2	507·0 538·3 514·7 } 520·0	1000 : 1170
854·5 937·9 } 896·2	1113·3 1024·0 } 1068·6	1000 : 1192
	Mean ratio of strengths......	1000 : 1181

Results of products and ratio to resist impact.

Product of strength by ultimate deflection in Cold Blast Iron.	Product of strength by ultimate deflection in Hot Blast Iron.	Ratio of products, or of power to resist impact.
629·3 564·0 588·4 } 593·9	662·6 779·5 690·2 } 710·7	1000 : 1196
259·9 340·3 } 300·1	403·8 337·6 } 370·7	1000 : 1205
	Mean ratio of power to sustain impact......	1000 : 1201

Table IX.—Scotch Iron.—Muirkirk No. 1, Cold Blast.

Experiment 1. Depth of bar, 1·015; Breadth do. 1·007; Distance between supports 4 ft. 6 in.			Experiment 2. Depth of bar, 1·049; Breadth do. 1·025; Distance between supports 4 ft. 6 in.			Experiment 3. Depth of bar, 1·013; Breadth do. 1·003; Distance between supports 2 ft. 3 in.			Experiment 4. Depth of bar, 1·042; Breadth do. 1·025; Distance between supports 2 ft. 3 in.		
Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.
28	·076	...	28	·067	...	112	·035	...	112	·035	...
56	·150	+	56	·133	+	224	·076	...	224	·070	...
112	·298	·013	112	·267	·010	336	·117	+	336	·112	+
168	·471	·030	168	·421	·027	448	·160	·007	448	·152	·007
224	·660	·053	224	·589	·049	560	·206	·010	560	·192	·011
280	·862	·085	280	·767	·077	672	·250	·018	952	·400	
336	1·096	·131	336	·961	·111	784	·309	·029	980	broke	
392	1·339	·186	392	1·177	·159	896	·377	·045			
448	1·650	·284	448	1·420	·227	952	·410				
476	broke		476	1·554		1008	broke				
			483	broke							
∴ Ultimate deflection = 1·781. Broke at the centre.			∴ Ultimate deflection = 1·583. Broke at the centre.			∴ Ultimate deflection = ·440. Broke $\frac{1}{2}$ an inch from the centre.			∴ Ultimate deflection = 412. Broke $\frac{5}{8}$ of an inch from the centre.		

The Muirkirk No. 1 cold blast, is a remarkably fine soft iron, with large, open, and brilliant crystals, of a blueish grey colour; it presents great regularity in its crystalline structure, the crystals slightly diminishing in size as they recede from the centre. In its working properties, as well as appearance, it is much akin to the Elsicar and Low Moor irons, and from its fluidity and strength may be safely used for every purpose of casting.

Results reduced to those of bars 1·00 *inch square.*

	Specific gravity.	Modulus of elasticity in lbs.	Breaking weight (b).	Ultimate deflection (d).	Product $b \times d$, or power of resisting impact.
Experiment 1st, bar 4 ft. 6 in. between supports	7050	14050600	458·8	1·808	829·5
Experiment 2nd, bar 4 ft. 6 in. between supports	7177	13956500	428·2	1·660	710·8
Mean...	7113	14003550	443·5	1·734	770·1
Experiment 3rd, bar 2 ft. 3 in. between supports	....	....	979·3	·4457	436·5
Experiment 4th, bar 2 ft. 3 in. between supports	....	....	880·6	·4293	378·0
Mean...	....	....	929·9	·4375	407·2

TABLE X.—Muirkirk No. 1 Pig Iron, Hot Blast.

EXPERIMENT 1.			EXPERIMENT 2.			EXPERIMENT 3.			EXPERIMENT 4.		
Depth of bar, 1·015 Breadth do. 1·010 Distance between supports 4 ft. 6 in. Weight of bar 5 ft. long.			Depth of bar, 1·025 Breadth do. 1·035 Distance between supports 4 ft. 6 in. Weight of bar 5 ft. long.			Depth of bar, 1·020 Breadth do. 1·020 Distance between supports 2 ft. 3 in.			Depth of bar, 1·035 Breadth do. 1·029 Distance between supports 2 ft. 3 in.		
Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.	Weight in lbs.	Deflection in inches.	Deflection, Load removed.
28	·079	...	28	·069	...	112	·043	...	112	·037	...
56	·160	+	56	·144	+	224	·090	·005	224	·073	+
112	·326	·013	112	·287	·011	336	·138	·008	336	·112	·005
168	·507	·029	168	·445	·021	448	·185	·010	448	·152	·008
224	·700	·051	224	·610	·036	560	·231	·015	560	·190	·011
280	·909	·082	280	·780	·059	672	·289	·022	672	·230	·014
336	1·141	·129	336	·978	·090	784	·357	·039	784	·277	·020
392	1·428	·207	392	1·190	·135	812	broke		896	·328	·031
420	1·571		420	1·310					952	·354	
441	broke		448	broke					1008	broke	
∴ Ultimate deflection = 1·668. Broke $2\frac{3}{8}$ inches from the centre.			∴ Ultimate deflection = 1·412. Broke $2\frac{3}{8}$ inches from the centre.			∴ Ultimate deflection = ·371. Broke $\frac{1}{2}$ an inch from the centre.			∴ Ultimate deflection = ·378. Broke at the centre.		

This iron is inferior to the Muirkirk No. 1 cold blast; it is what is technically called *Kishie*, or full of a great variety of rich crystals sparkling in the midst of a duller and more compact mass; an appearance which is invariably present in irons of great fluidity and richness.

In the turning and filing process it is superior to the Carron No. 2 cold blast, and equal in every other respect, except strength, to any of the former irons we have experimented upon.

Results reduced to those of bars 1·00 *inch square.*

	Specific gravity.	Modulus of elasticity in lbs.	Breaking weight (b).	Ultimate deflection (d).	Product $b \times d$, or power of resisting impact.
Experiment 1st, bar 4 ft. 6 in. between supports	6948	12805700	423·8	1·693	717·5
Experiment 2nd, bar 4 ft. 6 in. between supports	6959	13783100	412·0	1·447	596·1
Mean...	6953	13294400	417·9	1·570	656·8
Experiment 3rd, bar 2 ft. 3 in. between supports	.. ...	......	765·2	·3784	289·5
Experiment 4th, bar 2 ft. 3 in. between supports	......	......	914·5	·3912	357·8
Mean...	......	......	839·8	·3848	323·6

Comparative Results of Muirkirk Iron No. 1.

Distance between supports 4 ft. 6 in. and 2 ft. 3 in.

Strength of the Cold Blast Iron.	Strength of the Hot Blast Iron.	Ratio of the Strengths.
458·8, 428·2 } Mean 443·5	423·8, 412·0 } Mean 417·9	1000 : 942
979·3, 880·6 } 929·9	765·2, 914·5 } 839·8	1000 : 912
	Mean ratio of strength......	1000 : 927

The products and ratio to resist impact.

Product of strength by ultimate deflection in Cold Blast Iron.	Product of strength by ultimate deflection in Hot Blast Iron.	Ratio of products, or of power to resist impact.
829·5, 710·8 } 770·1	717·5, 596·1 } 656·8	1000 : 852
436·5, 378·0 } 407·2	289·5, 357·8 } 323·6	1000 : 794
	Mean ratio of power to sustain impact......	1000 : 823

Modulus of elasticity in lbs. for a base of an inch square.

Cold Blast Iron......	14,050,600
Ditto..................	13,956,500
Mean......	14,003,550
Hot Blast Iron......	12,805,700
Ditto..................	13,783,100
Mean......	13,294,400

Effects of Time.

In former experiments on the transverse strength of cast iron, it has been assumed that the elasticity remained perfect to the extent of $\frac{1}{3}$rd at least of the breaking weight. This assumption, which has been attempted to be proved by Tredgold, has gained considerable credence; but so far as I can perceive there appears to be no ground for such an opinion. In the earlier experiments on the subject of hot and cold blast irons, it was observed by Mr. Hodgkinson that in some cases the elasticity was considerably injured with $\frac{1}{5}$th or $\frac{1}{6}$th of the breaking weight. This fact was of such importance as to induce me to pay considerable attention to the set in the preceding tables, and also to note the defects of elasticity in those that follow, up to the time

of the weights becoming permanent upon the bars. From the methods thus adopted it will be seen that the value of the set has been given with the deflections at regular intervals of weights, from the commencement of the experiment to the time of fracture, and the connection between the weights, deflections, and set, will therefore in all probability be better observed.

The early period at which the elasticity became injured caused in addition to the above an extended series of experiments, to determine whether such injury to the elasticity would not (with the weight continued) ultimately break the bar. This became a debatable and very important question between Mr. Hodgkinson and myself, the one contending for time, and the other for a permanent state of elasticity in the ratio of the loads and the forces respectively.

The inquiry therefore was, to what extent can cast iron be loaded, or how much would it permanently bear without endangering its security? This was in reality a question of great interest, one which involved important considerations, such as the stability of bridges, warehouses, factories, and many other erections to which cast iron is applied, and which depends almost entirely upon our knowledge of its ductility and strength.

It assuredly must be of importance to know that a material of such value, and so extensively used in almost every branch of art, can be trusted, and that we may with safety depend upon its security throughout the endless variety of forms and strains to which it is subjected.

Cast iron has hitherto been considered a brittle, and by many persons an insecure material; yet, notwithstanding the distrust and suspicion with which it was viewed, it still continues to increase in demand, and that to a great extent, in most countries where the arts are cultivated. Every inquiry therefore which tends to exhibit its peculiar properties as respects strength, ductility, &c., must be regarded as an additional step towards a greater degree of security in its application. Under these impressions the following experiments were instituted.

Five bars of cold, and five of hot blast, Coed-Talon No. 2 iron, cast to be one inch square, were selected, and having loaded them with different weights, with their ends supported on props 4 feet 6 inches asunder, they were left in this position, to determine how long they would sustain the loads without breaking.

It is now upwards of 15 months since the bars were charged, and if we are to judge from the hardihood displayed in their resistance to the load, there is every chance of a long and protracted experiment. In fact, there is every probability of the experiments outliving the experimenter.

Table XI.

Table of deflections as exhibited with permanent weights of 280 lbs. suspended from the centre of bars of cold and hot blast Coed-Talon iron, cast to be one inch square, and left to determine the effect produced on each bar after given intervals of time.

Distance between supports 4 ft. 6 in.

Experiment 1. Cold blast iron No. 2, Depth of bar, 1·050, Breadth do. 1·030			Date of Observation. 1837.	Temperature at the time of observation.	Experiment 2. Hot blast iron No. 2, Depth of bar, 1·050, Breadth do. 1·010			
Weight in lbs.	Observed deflection in inches.	Deflection, Load removed.			Weight in lbs.	Observed deflection in inches.	Deflection, Load removed.	
56	·144	...	....	......	56	·153	......	
112	·309	·020	....	......	112	·337	·022	
168	·499	...	....	......	168	·548	.. ...	
224	·708	·075	....	......	224	·784	·088	The permanent weight, 280 lbs. was fixed stationary upon the cold blast bar at 6 o'clock p.m., March 8th 1837, and an equal weight was left to remain upon the hot blast bar on the following day at 10 a.m.
280	·916	·108	March 9th	49°	280	1·043	·132	
280	·930	...	Do. 11th	......	280	1·064	......	
280	·932	...	Do. 17th	......	280	1·067	......	
280	·930	...	April 15th	47	280	1·078	......	
280	·932	...	May 31st	62	280	1·082	......	
280	·937	...	Aug. 22nd	70	280	1·086	......	
280	·942	...	Nov. 18th	45	280	1·083	......	
280	·941	...	Jan. 8, 1838	38	280	1·086	......	
280	·945	...	March 12th	51	280	1·091	......	
280	·963	...	June 23rd	78	280	1·107	......	From observations taken

this day, June 23rd, the mean deflection for 15 months was found to be, for cold blast ·936, increase ·004, for hot blast, 1·079, increase ·012.

Results in the preceding Table, showing the progressive and increased ratio of deflections from March 11*th*, 1837 *to June* 23*rd*, 1838.

Cold Blast Iron, deflection in inches.	Date of Observation.	Temp.	Hot Blast Iron, deflection in inches.	Ratio of increase of deflections.
1·684	March 11th, 1837	....	1·064	....
1·824	June 23rd, 1838	78°	1·107	....
·033	Increase	....	·043	1000 : 1303

From the above it appears, that a progressive increase, in the deflections of the bars, has taken place, since the time they were charged, in the ratio of 1000, for the cold blast, to 1303, for the hot blast.

The hot blast bar in these experiments being more deflected than the cold blast, indicates that the particles are more extended and compressed in the former iron, with the same weight, than in the latter. This excess of deflection may in some degree account for the rapidity of increase, which it will be observed is considerably greater in the hot than in the cold blast bar.

The next experiment was from the same metal, cast as before into rectangular bars 1 inch square, and loaded with additional weights, amounting to 336 lbs. on each bar.

Table XII.

Table of deflections as exhibited with permanent weights of 336 lbs. suspended from the centre of bars of cold and hot blast Coed-Talon iron, cast to be one inch square, and left to determine the effect produced on each bar after given intervals of time.

Distance between the supports 4 ft. 6 in.

Experiment 1. Cold Blast Iron No. 2 Breadth of bar, 1·020 Depth do. 1·030					Experiment 2. Cold Blast Iron No. 2 Breadth of bar, 1·020 Depth do. 1·040			
Weight in lbs.	Observed deflection in inches.	Deflection, Load removed.	Date of observation. 1837 & 1838.	Temperature at the time of observation.	Weight in lbs.	Observed deflection in inches.	Deflection, Load removed.	
56	·148	......	....	......	56	·160	......	The weight, 336 lbs., was left permanent on the cold blast bar on Friday, March 3rd, at six o'clock p.m. The same weight (336 lbs.) was fixed stationary upon the hot blast bar on Tuesday, March 7th, at 11 o'clock, a.m.
112	·318	·028	....	......	112	·346	·026	
168	·515	......	....	......	168	·567	......	
224	·732	·086	....	......	224	·809	·092	
280	·961	......	....	......	280	1·077	......	
336	1·221	·192	....	......	336	1·374	·212	
			1837					
336	1·267		March 6th	......	......	......		When the weights, 336 lbs. were placed on the cold blast bars, after the elasticity had been taken, the deflection increased from 1·221 to 1·267.
336	1·270		Do. 9th	49°	336	1·454		
336	1·270		Do. 11th	49	336	1·461		
336	1·271		Do. 17th	49	336	1·462		
336	1·271		April 15th	47	336	1·475		On the hot blast bar the deflection increased with the restoration of the weights from 1·374 to 1·397.
336	1·274		May 31st	62	336	1·481		
336	1·288		Aug. 22nd	70	336	1·504		
336	1·286		Nov. 18th	45	336	1·499		
			1838					
336	1·288		Jan. 8th	38	336	1·502		The mean deflection under various temperatures is, for the cold blast 1·280, increase ·009; for the hot blast 1·486, increase ·024.
336	1·298		March 12th	51	336	1·505		
336	1·316		June 23rd	78	336	1·538		

Results in the preceding Table, showing the progressive and increased ratio of deflections from the 11*th of March,* 1837, *to* 23*rd of June,* 1838.

Cold Blast Iron, deflection in inches.	Date of Observation.	Temperature.	Hot Blast Iron, deflection in inches.	Ratio of increase of deflections.
1·270	March 11th, 1827	....	1·461	
1·316	June 3rd, 1838	78°	1·538	
·046	Increase	....	·077	1000 : 1673

The ratio of increase is here much greater than what is indicated by the lesser weights—280 lbs.—in Table, No. XI. The progression towards fracture (providing we assume a progressive yielding in that direction) is advancing at a quicker rate in this case than with the lighter loads; consequently the resisting powers are becoming gradually weaker. We must however observe, that the temperature of the air in the room where the bars are placed was at 78° when the last observations were made, whereas the temperature was only 46° at the time the bars were first loaded. This difference in the temperature will give rather greater deflections, from the expansion produced on the bars in a medium of 78°. In confirmation of this opinion I would beg to refer to the observations of November 18th, when the atmosphere of the room was at 45°; the deflections had then decreased from 1·288 to 1·286 in the cold blast iron, and from 1·504 to 1·499 in the hot blast iron.

Table XIII.

Table of deflections as exhibited with permanent weights of 392 lbs. suspended from the centre of bars of Cold and Hot Blast Coed-Talon Iron, cast to be one inch square and left to determine the effect produced on each bar after given intervals of time.

Distance between supports 4 feet 6 inches.

Experiment 1. Cold Blast Iron No. 2 Depth of bar, 1·030 Breadth do. 1·020			Date of Observation. 1837 & 1838.	Temperature at the time of observation.	Experiment 2. Hot Blast Iron No. 2 Depth of bar, 1·050 Breadth do. 1·000			
Weight in lbs.	Observed deflection in inches.	Deflection, Load removed.			Weight in lbs.	Observed deflection in inches.	Deflection, Load removed.	
56	·153	·005			56	·150		The weight, 392 lbs., was fixed stationary on the cold blast bar on Friday, March 3rd, at 12 o'clock, and the same weight was placed upon the hot blast bar at 11 o'clock, a.m., on the following day.
112	·334	·022			112	·333	·023	
168	·541	...			168	·551	...	
224	·769	·089			224	·775	·086	
280	1·013	...			280	1·029	...	
336	1·294	·199			336	1·311	·188	
392	1·616	·292			392	1·635	·272	
392	1·684		March 6th		392	1·715		On re-instating the weight after the deflection and defects of elasticity had been taken, the deflection had increased in the cold blast from 1·616 to 1·636, and from 1·635 to 1·661 in the hot blast.
392	1·694		... 9th	49°	392	1·758		
392	1·694		... 11th		392	1·760		
392	1·694		... 17th		392	1·763		
392	1·716		April 15th	47°	392	1·767		
392	1·725		May 31st	62°	392	1·775		
392	1·737		Aug. 2nd	70°	392	1·783		Mean deflection throughout all the changes of temperature in 15 months—
392	1·724		Nov. 18th	45°	392	1·773		
			1838.					
392	1·722		Jan. 8th	38°	392	1·773		For the cold blast 1·742, increase ·048; hot blast 1·777, increase ·014.
392	1·801		March 12th	51°	392	1·784		
392	1·824		June 23rd	78°	392	1·803		

Results in the preceding Table, showing the progressive and increased ratio of deflections from March 11*th*, 1837, *to June* 23*rd*, 1838.

Cold Blast Iron, deflection in inches.	Date of observation.	Temp.	Hot Blast Iron, deflection in inches.	Ratio of increase of deflections.
1·684	March 6th 1837	....	1·715	......
1·824	June 23rd 1838	78°	1·803	......
·140	Increase.	....	·088	1000 : 628

On comparing the above with Table No. XII, preceding it, there will be found a greater proportionate deflection in both the cold and hot blast bars than is observable with the lighter weights of 336 lbs., and in both instances the deflection is greater in the hot than in the cold blast. The same is the case in experiment 2nd of the next Table, where the deflection indicated by 448 lbs. is less than what is exhibited on the hot blast with 336 lbs., being as 1·437 to 1·803. This may be accounted for by the bars which were newly cast containing, in all probability, a greater proportion of carbon, and consequently having more ductility than those in Tables No. XII and No. XIV.

The ratio of increase in the deflections is much higher in the cold blast iron than the hot; and notwithstanding the silent and apparently progressive approach towards rupture, there is every appearance of a long and tedious experiment. It cannot however be doubted that fracture will sooner take place in the cold than the hot blast, as the former is advancing to that point with greater rapidity, or in the ratio of 1000 to 628. We may therefore expect the bar from the cold blast iron to be the first to give way, and probably about the time when the deflection verges on two inches.

TABLE XIV.

Table of deflections as exhibited with permanent weights of 448 lbs. suspended from the centre of bars of cold and hot blast Coed-Talon iron, cast to be one inch square, and left to determine the effect produced on each bar after given intervals of time.

Distance between supports 4 feet 6 inches.

Experiment 1. Cold Blast Iron No. 2. Depth of bar 1·000 Breadth do. 1·010			Experiment 2. Cold Blast Iron No. 2. Depth of bar 1·020 Breadth do. 1·030			Date of Observation.	Temperature.	Experiment 3. Hot Blast Iron No. 2. Depth of bar 1·040 Breadth do. 1·010			Remarks.
Weight in lbs.	Observed deflection in inches.	Deflection, Load removed.	Weight in lbs.	Observed deflection in inches.	Deflection, Load removed.	1837 & 1838.		Weight in lbs.	Observed deflection in inches.	Deflection, Load removed.	
56	·155	...	56	·129	...			56	·165	...	The permanent weights, 448 lbs., were placed, in experiment 1, upon the cold blast bar on Saturday, the 4th March, at 4 o'clock p.m., 1837, and the same weights became stationary on the cold blast bar, in experiment 2, on the previous day, at 4 o'clock p.m. In experiment 3, 392 lbs. broke the bar; several other bars of hot blast were tried, but they successively broke on laying on the weights, 448 lbs. Mean deflection for 15 months, ending 23rd June, was for cold blast 1·431, increase 0·28.
112	·333	·021	112	·264	·009			112	·360	·025	
168	·536	....	168	·416	...			168	·579	...	
224	·755	·076	224	·578	·039			224	·829	·086	
280	·992	...	280	·754	...			280	...	...	
336	1·262	·167	336	·934	·087			336	1·419	·208	
392	1·556	...	392	1·131	...			392	broke with this weight.		
448	1·904	...	448	1·361	·192						
						1837.					
448	1·964	·404	448	1·410	...	March 6					
448	2·005	...	448	1·413	...	... 9	49°				
448	2·005	...	448	1·413	...	... 11					
448	2·010	...	448	1·413	...	... 17					
448	2·014	broke after sustaining the load 37 days. The deflection increased from 1·904 to 1·964 after the defects of elasticity were last taken.									
			448	1·422		April 15	47°				
			448	1·424		May 31	62°				
			448	1·438		Aug. 22	70°				
			448	1·431		Nov. 18	45°				
						1838.					
			448	1·430		Jan. 8	38°				
			448	1·439		March 12	51°				
			448	1·457		June 23	78°				

Results in the preceding Table, showing the progressive and increased ratio of deflections from March 6th, 1837, *to June 23rd,* 1838.

Cold Blast Iron, deflection in inches.	Date of Observation.	Temp.	Hot Blast Iron, deflection in inches.	Ratio of increase of deflections.
Experiment 3.				
1·410	March 6th, 1837.		....	....
1·457	June 23rd, 1838.	70°	....	....
·047	Increase	...	....	....

The greater degree of weakness here exhibited in the hot blast iron than the cold renders our comparative experiments in this Table defective; several bars were tried in succession, but they separately gave way, some on laying on the load, 448 lbs., and others after supporting it for a few seconds.

In experiment 1st, Table XIV., it will be noticed that a bar from the cold blast iron, after being charged with the full load, 448 lbs., continued to support it for a period of 37 days; this was not however accomplished without signs of weakness, as will be seen from the progressive increase which took place in the deflections from the 6th to the 17th of March; and also from observed discrepancies sometime previous to its rupture. In making these statements it must be observed, that the bar in experiment 1st was thinner than any of the others, and had borne for thirty-seven days a weight greater than had broken bars of the same size in previous experiments upon the Coed-Talon iron, when the weights were laid on without loss of time.

Abstract of comparative increase and ratio of deflections on the whole bars from March 6th, 1837, *to June 23rd,* 1838.

	Cold Blast Iron, increase of deflection in inches.	Hot Blast Iron, increase of deflection in inches.	Ratio of deflections.
Increase of deflection, Table XI.	·033	·043	....
Increase of deflection, Table XII.	·046	·077	....
Increase of deflection, Table XIII.	·140	·088	....
Increase of deflection, Table XIV.	·047	......	....
Mean...	·066	·069	1000 :1045

The mean increase of deflections on the whole bars is therefore ·066 for the cold blast, and ·069 for the hot blast, being in the ratio of 1000 to 1045.

The interest which experiments of this kind may be expected to excite, and the nature as well as the value of the material on which they are here made, will, it is hoped, prove an inducement for extended investigation on this subject.

There cannot be a doubt that the phenomenon of cohesive force is strongly developed in the preceding tables; the minute crystalline particles of the bars are acted upon by loads, which, in the heavier weights, are almost sufficient to produce fracture: yet fracture is not (except in one instance) produced, and to what extent the power of resistance may yet be carried is left for time to determine. It nevertheless appears from the present state of the bars (which indicate a slow but progressive increase in the

deflections) that we must at some period arrive at a point beyond their bearing powers; or otherwise to that position which indicates a correct adjustment of the particles in equilibrium with the load. Which of the two points we have in this instance attained is difficult to determine: sufficient data are however adduced to show that the weights are considerably beyond the elastic limit*, and that cast iron will support loads to a much greater extent than what has usually been considered safe, or beyond that point where a permanent set takes place. But in whatever way this may be determined, it is obvious the preceding experiments give greater indications of strength than has generally been supposed cast iron would do; and should the bars continue to support the loads for a few years longer, there cannot exist a doubt as to the security of this metal under applications hitherto unknown; and the same may be said of other materials.

In the 14th Table we shall find inch square bars loaded on the middle, within a few pounds of weights sufficient to break them; we shall also find the bars considerably bent, and the resisting powers in full operation to sustain the load. Now the question to be determined by this experiment is, the nature of this resistance; and to show in the first instance whether the resisting power of the extended particles below, and the powers of the condensed ones operating above, are sufficient at all times *ad infinitum* to support the load; or whether those particles, instead of being united (as we suppose) with a permanent force, nicely balanced at all points of resistance, are not absolutely giving way; and by slow, though imperceptible degrees, becoming hourly weaker, until the cohesive power is entirely destroyed and rupture takes place.

It is not my intention in this place to offer any opinion upon the cohesive properties of matter, but simply to inquire how far the bearing powers of cast iron can be depended upon.

It is evident from these experiments that both sorts of hot and cold blast iron possess that power in a high degree; and we need only refer to the experiments for examples to show the patient tenacity with which so heavy a load is supported. At first sight it would appear, that the heavier loaded bars were progressively giving way, as the deflections continue to increase since the loads were permanently fixed; this defect is however not more conspicuous in the bars supporting 448 lbs., than in those sup-

* The elastic limit is that point where bodies under strain lose the power to restore themselves when the load is removed; a property which is strongly exemplified in cast iron. It has been considered by many that materials cannot be loaded with safety beyond that point.

porting 392 lbs.; the deflection is even greater in the latter, arising in all probability from a greater degree of ductility in the bars.

I hope shortly to induce my friend Mr. Hodgkinson, Professor Barlow, or some other able mathematician, to investigate this subject, and by close analysis to demonstrate those truths, so essential to the interests of all engaged in the use of the metals, but more particularly in reference to the security of the public at large.

Effects of Temperature.

When the multiplicity of objects to which cast iron is applied, and the innumerable situations in which it is placed, is considered, I may venture to state, that in every work of which cast iron forms the whole or a part of the structure, it is more or less liable to change. The rapidity with which it imbibes, and the facility with which it parts with caloric, is in itself a sufficient consideration for the labour I have bestowed upon these inquiries.

The present investigation would have been less satisfactory had the experiments on the effects of temperature been omitted; and I trust, the annexed Tables, which exhibit hot and cold blast iron under various gradations of heat, will not be without their uses in the future application of this material.

Rondelet, in his "*Traite de Bâtir,*" has given and collected results from experiments, made by himself and others, on the expansion of bodies under the effects of heat; but I am not aware of any that have been made to ascertain the transverse strength of metallic substances under the various changes of temperature. It is well known that the effects of heat upon iron have not escaped the notice of philosophers; but I believe no writers on this subject have conducted their experiments in any way analogous to those now under consideration.

The celerity with which heat passes through the metals, and the frequent recurrence of iron being the medium of communication between fluids and this powerful agent, it is not surprising that the changes of temperature thus induced should cause such visible indications of deterioration in the material. Gas retorts, and all those vessels exposed to the alternate changes of the heating and cooling process, are considerably injured by the expansion and contraction of the parts; and no doubt the destruction of the metals is much accelerated when they are worked up to a high and excessive temperature. Probably steam-boilers are not so much injured as those above-mentioned, as the temperature is kept moderately low by the water

they contain, which seldom exceeds 212°. The same causes are, nevertheless, in operation, and must continue to be so under the varied influences of caloric action.

Had time permitted, it was my intention to have pursued the experiments on temperature under a much greater degree of form and change than is here exhibited. For example, it might have been desirable not only to load the bars until they were broken, but also to charge them with different weights, and, by alternate heating and cooling, to have ascertained how far the bars so charged were affected by the change. Such an extension of the experiments might have led to the development of some new feature in the actions thus produced, and that more particularly by the introduction, abstraction, re-introduction, &c. of the different increments of heat. As it is, the bars were all broken at the temperatures indicated in the tables.

Table XV.

Coed-Talon, Cold Blast.

To determine the relative strengths of Coed-Talon Hot and Cold Blast Iron, to resist a transverse strain under different degrees of temperature.

No. 2 Iron. Experiment 1.				No. 2 Iron. Experiment 2.				No. 2 Iron. Experiment 3.				No. 2 Iron. Experiment 4.				No. 2 Iron. Experiment 5.			
Depth of bar, 1·068 Breadth of do. 1·024 Distance between supports 2 ft. 3 in.				Depth of bar, 1·020 Breadth of do. 1·005 Distance between supports 2 ft. 3 in.				Depth of bar, 1·008 Breadth of do. ·996 Distance between supports 2 ft. 3 in.				Depth of bar, 1·006 Breadth of do. 1·021 Distance between supports 2 ft. 3 in.				Depth of bar, 1·038 Breadth of do. 1·023 Distance between supports 2 ft. 3 in.			
Weight in lbs.	Deflection in inches.	Permanent set.	Temp. Fahr.	Weight in lbs.	Deflection in inches.	Permanent set.	Temp. Fahr.	Weight in lbs.	Deflection in inches.	Permanent set.	Temp. Fahr.	Weight in lbs.	Deflection in inches.	Permanent set.	Temp. Fahr.	Weight in lbs.	Deflection in inches.	Permanent set.	Temp. Fahr.
112	·034	...	26°	112	·041	+	28°	112	·040	+	32°	112	·035	...	32°	112	·034	...	114°
224	·071	·007	...	224	·090	·009	...	224	·076	·007	...	224	·074	...	...	224	·072	+	...
336	·101	·010	...	336	·132	·011	...	336	·117	·010	...	336	·114	+	...	336	·104	·005	...
448	·142	...	...	448	·187	...	...	448	·156	·013	...	448	·151	·007	...	448	·144	·008	113°
560	·189	·017	...	560	·242	·027	...	560	·197	·018	...	560	·204	·012	...	560	·182	·013	...
672	·224	·031	...	672	·310	...	...	672	·244	·024	...	672	·252	·021	...	672	·224	·019	...
784	·271	·030	...	784	·382	·053	...	784	·296	·035	...	784	·311	·033	...	784	·274	·028	112°
896	·341	...	...	896	·461	·082	...	896	·352	·049	...	896	·374	·051	...	896	(·324)	broke	
994	broke	...	...	938	broke	...	...	952	(·380)	broke	...	980	(·420)	broke	...				
∴ Ultimate deflection = ·385.—This bar was broken in the open air during intense frost.				∴ Ultimate deflection = ·487.—This bar was broken in the open air.				This bar was broken when buried in snow.				This bar was broken when buried in snow.				Broken in water.			

The microscopic appearance of this iron will be found at No. I. Table, on the transverse strain.

Results reduced to those of bars 1·00 *inch square, and 2 feet 3 inches between the supports.*

	Temperature.	Specific gravity.	Modulus of elasticity.	Breaking weight (*b*).	Ultimate deflection (*d*).	Product *b*×*d*, or power of resisting impact.
Experiment 1st, No. 2 iron......	26°	6·955	12994400	851	·411	349·8
Experiment 2nd, No. 2 do.	28°	......	12603700	897	·4967	445·6
Mean...	...	6·955	12799050	874	·4538	397·7
Experiment 3rd, No. 2 iron......	32°	6·955	13506700	940·7	·383	360·3
Experiment 4th, No. 2 do.	32°	......	15148200	958·5	·422	404·5
Mean...	...	6·955	14327450	949·6	·402	382·4
Experiment 5th, No. 2 iron......	113°	6·955	14168000	812·9	·336	273·1

Table XVI.

Coed-Talon, Hot Blast.

No. 2 Iron. Experiment 1.

Depth of bar, 1·056
Breadth of do. 1·004
Distance between supports 2 ft. 3 in.

Weight in lbs.	Deflection in inches.	Permanent set.	Temp. Fahr.
112	·030	...	16°
224	·069	+	...
336	·108	·008	...
448	·150	...	...
560	·199	·018	...
672	·251	...	...
784	·314	·039	...
896	broke	...	...

∴ Ultimate deflection = ·366.—This bar was broken during intense frost.

No. 2 Iron. Experiment 2.

Depth of bar, 1·030
Breadth of do. 1·010
Distance between supports 2 ft. 3 in.

Weight in lbs.	Deflection in inches.	Permanent set.	Temp. Fahr.
112	·035	...	16°
224	·075	+	...
336	·120	·008	...
448	·166	...	...
560	·220	·020	...
672	·292	...	...
784	·351	·045	...
882	broke	...	...

∴ Ultimate deflection = ·402. Broken in the open air.

No. 2 Iron. Experiment 3.

Depth of bar, 1·033
Breadth of do. 1·012
Distance between supports 2 ft. 3 in.

Weight in lbs.	Deflection in inches.	Permanent set.	Temp. Fahr.
112	·036	+	32°
224	·075	·006	...
336	·114	·010	...
448	·155	·016	...
560	·203	·022	...
672	·246	·031	...
784	·304	·041	...
896	·363	·054	...
1008	(·422)	broke	...

This bar was broken when buried in snow.

No. 2 Iron. Experiment 4.

Depth of bar, 1·020
Breadth of do. 1·010
Distance between supports 2 ft. 3 in.

Weight in lbs.	Deflection in inches.	Permanent set.	Temp. Farh.
112	·036	...	32°
224	·074	+	...
336	·114	·005	...
448	·154	·009	...
560	·202	·014	...
672	·252	·024	...
784	·312	·039	...
896	·381	·060	...
952	(·415)	broke	...

This bar was broken when buried in snow.

No. 2 Iron. Experiment 5.

Depth of bar, 1·006
Breadth of do. 1·009
Distance between supports 2 ft. 3 in.

Weight in lbs.	Deflection in inches.	Permanent set.	Temp. Fahr.
112	·037	...	85°
224	·077	+	...
336	·123	·007	...
448	·170	·013	...
560	·223	·022	...
672	·277	·031	...
784	·348	·051	84°
896	(·419)	broke	

Broken in water.

Results reduced to those of bars 1·00 inch square, and 2 ft. 6 in. between the supports.

	Temperature.	Specific gravity.	Modulus of elasticity.	Breaking weight in lbs. (b).	Ultimate deflection (d).	Product $b \times d$, or power of resisting impact.
Experiment 1st, No. 2 iron......	16°	6·968	15538300	800·29	·3865	309·3
Experiment 2nd, No. 2 do.	24°	......	14267500	823·10	·4140	340·8
Mean...	...	6·968	14902900	811·69	·4002	325·0
Experiment 3rd, No. 2 iron......	32°	6·968	13723500	933·4	·436	406·9
Experiment 4th, No. 2 do.	32°	......	14283200	906·0	·423	383·2
Mean...	...	6·968	14003350	919·7	·429	395·0
Experiment 5th, No. 2 iron......	84°	6·968	14500000	877·5	·421	369·4

The infusion of heat into a metallic substance may render it more ductile, and probably less rigid in its nature; and I apprehend it will be found weaker, and less secure under the effects of heavy strain. This is observable to a considerable extent in the experiments ranging from 26° up to 190° of temperature.

The cold blast at 26° and 190°, is in strength as 874 : 743,
and
The hot blast at 21° and 190°, is in strength as 811 : 731;

being a diminution in strength as 100 : 85 for the cold blast, and 100 : 90 for the hot blast, or 15 per cent. loss of strength in the cold blast, and 10 per cent. in the hot blast.

Table XVII.—Coed-Talon Cold Blast.

To determine the relative strengths of Coed-Talon hot and cold blast iron to resist the transverse strain under different degrees of temperature.

No. 2 Iron. Experiment 6.

Depth of bar, 1·030
Breadth do. 1·030
Distance between supports 2 ft. 3 in.

Weight in lbs.	Deflection in inches.	Permanent Set.	Temperature Fahrenheit.
112	·034	...	...
224	·069	...	...
336	·106	+	...
448	·144	·009	193°
560	·185	·011	...
672	·231	·016	191
784	·281	·021	...
812	·293	broke	...

Broke in hot water.

No. 3 Iron. Experiment 7.

Depth of bar, ·995
Breadth do. 1·005
Distance between supports 2 ft. 3 in.

Weight in lbs.	Temp.
900 broke	212°

Broke in boiling water.

No. 3 Iron. Experiment 8.

Depth of bar, ·995
Breadth do. 1·000
Distance between supports 2 ft. 3 in.

Weight in lbs.	Temp.
934 broke	212°

Broke in boiling water.

No. 3 Iron. Experiment 9.

Depth of bar, 1·015
Breadth do. 1·021
Distance between supports 2 ft. 3 in.

Weight in lbs.	Temp.
956 broke	600°

Broke in melted lead.

No. 3 Iron. Experiment 10.

Depth of bar, ·987
Breadth do. ·997
Distance between supports 2 ft. 3 in.

Weight in lbs.	Temp.
1124 broke	600°

Broke in melted lead.

No. 2 Iron. Experiment 11.

Depth ... 1·004
Breadth 1·005
Distance between supports 2 ft. 3 in.

Weight in lbs.

672 broke it, after the weight had been on half a minute. The deflection was considerable. The weight was laid on at once. This bar was perceptibly red by daylight.

No. 3 Iron. Experiment 12.

Depth ... 1·026
Breadth 1·030
Distance between supports 2 ft. 3 in.

Weight in lbs.

784, broke. This bar was a deep orange colour in the dark. There was no time to measure the deflection.

Coed-Talon No. 3 cold blast iron exhibits greater density in the arrangement of its crystalline texture than the No. 2. Colour a whitish grey, interspersed with a number of minute luminous crystals.

Results reduced to those of bars 1·00 inch square, and 2 feet 4 inches between supports.

	Temperature Fahrenheit.	Modulus of elasticity.	Breaking weight (b).	Ultimate deflection (d).	Product $b \times d$ or power of resisting impact.
Experiment 6	193° – 191°	14398600	743·1	·301	223·7
Experiment 7	212°	....	905·0	....	....
Experiment 8	212	....	944·0	....	....
Mean	......	....	924·5	....	....
Experiment 9	600	....	909·0	....	....
Experiment 10	600	....	1157·0	....	....
Mean	......	....	1033·	....	....
Experiment 11	Redbydaylight	....	663·3	....	....
Experiment 12	Red in dark	....	723·1	....	....

TABLE XVIII.—Coed-Talon Hot Blast.

No. 2 Iron. Experiment 6.

Depth of bar, 1·007
Breadth do. 1·009
Distance between supports 2 ft. 3 in.

Weight in lbs.	Deflection in inches.	Permanent Set.	Temperature Fahrenheit.
12	·041	+	138°
24	·082	·006	...
36	·123	·010	...
48	·164	·017	...
60	·215	·021	138
72	·271	·036	...
84	·329	·051	...
96	...	broke	134

∴ Ultimate deflec-on = ·386.
Broke in hot water.

No. 2 Iron. Experiment 7.

Depth of bar, 1·038
Breadth do. 1·017
Distance between supports 2 ft. 3 in.

Weight in lbs.	Deflection in inches.	Permanent Set.	Temperature Fahrenheit.
112	·044	+	186
224	·094	·009	187
336	·142	·012	...
448	·198	·016	188
560	·263	·026	...
672	·333	·041	...
700	...	broke	...

∴ Ultimate deflection = ·346.
Broke in hot water.

No. 2 Iron. Experiment 8.

Depth of bar, 1·019
Breadth do. 1·015
Distance between supports 2 ft. 3 in.

Weight in lbs.	Deflection in inches.	Permanent Set.	Temperature Fahrenheit.
122	·037	+	196°
224	·075	·003	...
336	·115	·005	195
448	·151	·010	...
560	·205	·018	...
672	·255	·024	192
784	·314	·038	...
868	broke	...	190

∴ Ultimate deflection = ·356.
Broke in hot water.

No. 3 Iron. Experiment 9.

Depth of bar, ·993
Breadth do. ·991
Distance between supports 2 ft. 3 in.

Weight in lbs.	Temp.
800 broke	212°

Broke in boiling water.

No. 3 Iron. Experiment 10.

Depth of bar, ·986
Breadth do 1·000
Distance between supports 2 ft. 3 in.

Weight in lbs.	Temp.
811 broke	600°

Broke in melted lead.

No. 3 Iron. Experiment 11.

Depth of bar, ·986
Breadth do. ·997
Distance between supports 2 ft. 3 in.

Weight in lbs.	Temp.
889 broke	600°

Broke in melted lead.

No. 2 Iron. Experiment 12.

Depth of bar, 1·034
Breadth do. 1·010
Distance between supports 2 ft. 3 in.

Weight in lbs.
896 broke

Bar susceptibly red in the dark.

This iron presents an appearance of greater ductility and softness than the No. 3. cold blast. From the blue tinge which the fracture exhibits, it is evidently an iron possessing the powers of being worked to a greater degree than the cold blast.

Results reduced to those of bars 1·00 inch square, and 2 feet 3 inches between the supports.

	Temperature Fahrenheit.	Modulus of elasticity.	Breaking weight (b).	Ultimate deflection (d).	Product $b \times d$ or power of resisting impact.
Experiment 6th, bar No. 2 iron ...	138° – 134°	13046200	875·7	·389	340·6
Experiment 7th, bar No. 2 do. ...	186 – 188	11012500	638·8	·359	229·3
Experiment 8th, bar No. 2 do. ...	196 – 190	13869500	823·6	·363	298·9
Experiment 9th, bar No. 3 do. ...	212°	....	818·4	......	......
Experiment 10th, bar No. 3 do. ...	600	....	834·1	......	......
Experiment 11th, bar No. 3 do. ...	600	....	917·5	......	......
Mean......	......	....	875·8	......	......
Experiment 12th, bar No. 2 iron...	Red in the dark	....	829·7	......	......

In pursuing the experiments, it unfortunately occurred that the stock of No. 2 Coed-Talon metal became exhausted, a circumstance which interrupts the comparisons from below the freezing point to that of melted lead. The No. 3 should have been broken at all the points of temperature, in order to have ascertained the loss of strength sustained upon this iron by the increase of heat. This was however not accomplished, and we can now only compare the two qualities No. 2 and No. 3 at the boiling point of water, and then proceed to the temperature of melted lead. I have already noticed that a considerable failure of the strength took place after heating the No. 2 iron from 26° to 190°. At 212° we have in the No. 3 a much greater weight sustained than what is indicated by the No. 2 at 190°; and at 600° there appears in both hot and cold blast the anomaly of increased strength as the temperature is advanced from boiling water to melted lead, arising from the greater strength of the No. 3 iron.

A number of the experiments made on No. 3 iron of different sorts have given extraordinary and not unfrequently unexpected results. Generally speaking it is an iron of an irregular character, and presents less uniformity in its texture than either the first or second qualities; in other respects it is more retentive, and is often used for giving strength and tenacity to the finer metals.

Recurring to the No. 2 iron, it will be observed that the strength continued to diminish as the temperature was increased. Heating the cold blast iron in Experiments 11 and 12 to a perceptibly red colour, we have the breaking weights 663 and 723; whereas, in the hot blast, at nearly the same temperature, the breaking weight is 829·7, being as 693 (the mean) to 829, or in the ratio of 1000: 1289.

From the experiments in Table 1, it appears that a bar of cold blast iron 1 inch square and 2 feet 3 inches between the supports, broke at the ordinary temperature of the atmosphere with 836·9, and in No. 3 cold blast from Table 3, the breaking weight is 1137·3. This gives an excess of strength for the No. 3 iron of at least one-fourth.

When the bars were heated to a blood red the utmost care was taken to break them without loss of time. In every instance the deflection was considerable; rather more than 1½ inches was observed on the 2 feet 3 inches bars before they gave way.

Comparative strength and power to resist impact of the Coed-Talon hot and cold blast irons, at various temperatures.

Transverse Strengths.

Temperature.	Coed-Talon Cold Blast.	Coed-Talon Hot Blast.	Ratio.
Fahrenheit.	No. 2 Iron.	No. 2 Iron.	
26°	851·	823·1	1000 : 967·2
32	940·7, 958·5 (Mean 949·6)	933·4, 906·0 (Mean 919·7)	1000 : 977·6
190	743·1	823·6	1000 : 110·8
Red in dark	723·1	829·7	
	No. 3 Iron.	No. 3 Iron.	
212	905·0, 943·6 (Mean 924·3)	818·4, 834·1 (Mean 875·8)	1000 : 885·4
600	909·3, 1157·0 (1033·1)	917·5	1000 : 847·7

Power to resist impact.

Temperature.	Coed-Talon Cold Blast.	Coed-Talon Hot Blast.	Ratio.
Fahrenheit.	No. 2 Iron.	No. 2 Iron.	
26°	349·8	340·8	1000 : 974
32	360·3, 404·5 (Mean 382·4)	406·9, 383·2 (Mean 395·0)	1000 : 1032·9
190	223·7	298·9	1000 : 1336

Modulus of elasticity in lbs. for a base of 1 inch square.

Temperature.	Coed-Talon Cold Blast.	Coed-Talon Hot Blast.
Fahrenheit.	No. 2 Iron.	No. 2 Iron.
26°	12994400	14267500
32	13506700, 15148200 (Mean 14327450)	13723500, 14283200 (Mean 14003350)
190	14398600	13869500

The above summary of results on the strength of the hot and cold blast irons is, with one exception, in favour of the cold blast. On the other hand, the power to resist impact appears, with one exception, also, on the side of the hot blast.

Having prosecuted these inquiries through a considerable range both of time and temperature, and having united my efforts to those of Mr. Hodgkinson on the transverse strain, I shall, before closing this report, give a general summary, with the results of which he has kindly favoured me, from all the irons experimented upon in this way.

Those results will exhibit in one column the relative and proportionate strength of each iron, and in the other the

ratio of the forces to resist impact. Before closing the experiments, it may, however, be proper to state that, in addition to the methods described in the preceding inquiry, that of grinding was adopted. For this purpose, an apparatus was made to grind each iron under an equal pressure, in order to ascertain the comparative resistances of different specimens of the same size, as compared with the results from chipping and filing given before. This was done with equal weights, upon equal sections, and during equal periods of time; and each piece was carefully weighed, in order to determine which of the irons was most easily reduced. Notwithstanding the care taken to ensure correct results, I was unable to procure data from which any thing satisfactory could be obtained. For instance, in the Coed-Talon, Elsicar, and Milton irons, each specimen (nearly cubical) was reduced, as in the Table below, where W is a constant weight.

	Weight before grinding.	Weight after grinding.	Loss.
	Grains.	Grains.	Grains.
Coed-Talon No. 2 cold blast iron	W + 56	W – 161	217
Coed-Talon No. 2 hot blast do.........	W + 264	W + 128	136
Elsicar .... cold blast do..........	W + 155	W + 14	141
Milton .... hot blast do..........	W + 211	W + 78	133

The above results, selected from upwards of fifty experiments, are given, not for the purpose of comparison, but in order to enable others to follow up the experiments with greater success. I am of opinion that something may be done in this way, providing cast-steel cutters are used instead of a grindstone, the interstices of which become filled with metallic particles during the process, as the specimens are reduced; consequently the surface of the stone becomes smoother, and the angular points blunted.

General Summary of Results, as derived from the experiments on the transverse strength of hot and cold blast iron.

		Ratio of strength, that of the cold blast being represented by 1000.	Ratio of powers to sustain impact (cold blast being 1000).
These irons are from Mr. Hodgkinson's experiments.	Carron iron ....No. 2...	1000 : 990·9	1000 : 1005·1
	Devon do. ....No. 3...	1000 : 1416·9	1000 : 2785·6
	Buffery do. ....No. 1...	1000 : 930·7	1000 : 962·1
	Coed-Talon do..........No. 2...	1000 : 1007	1000 : 1234
	Coed-Talon do..........No. 3...	1000 : 927	1000 : 925
	Elsicar and Milton do.	1000 : 818	1000 : 875
	Carron do................No. 3...	1000 : 1181	1000 : 1201
	Muirkirk do............No. 1...	1000 : 927	1000 : 823
	Mean...	1000 : 1024·8	1000 : 1226·3

The ultimatum of our inquiries made in this way, stand, therefore, in the ratio of strength, as 1000 for the cold blast, to 1024·8 for the hot blast; leaving the small fractional difference of 24·8 in favour of the hot blast.*

The relative powers to sustain impact are likewise in favour of the hot blast, being in the ratio of 1000 to 1226·3.

For the ratios of the powers of the hot and cold blast irons to resist a transverse strain for an indefinite period of time, and for the resisting powers of the same iron under variable temperatures, I must refer the reader to the results contained in their respective tables.

* The extraordinary properties of the Devon No. 3 iron in a great measure account for the difference which occurs between the strengths, as also the comparative powers to resist impact.

Report of the Committee on Waves, appointed by the British Association at Bristol in 1836, *and consisting of* Sir John Robison, K.H., *Secretary of the Royal Society of Edinburgh, and* John Scott Russell, Esq., M.A. F.R.S. *Edin.* (*Reporter*).

Since the period of their appointment, the Committee have been almost incessantly occupied in carrying on the researches committed to them. The extent and multifarious nature of the subjects of inquiry have rendered it impossible to terminate the examination of all of them in so short a time; but it is their duty to report the progress which they have made, and the partial results they have already obtained, leaving to the reports of future years such portions of the inquiries as they have not yet undertaken. As far as they can judge from present indications, there are wide fields of novel and important science opening up in this direction, which will furnish an ample harvest of rich knowledge for the labour of several succeeding seasons.

The *Subjects of Inquiry* with which the Committee were charged are the following:—

What is a Wave?—What are the varieties, phenomena, and laws of waves in regard to generation and propagation in various circumstances?

Of what nature are the *Waves of the Sea?*

Is the *Tidal Elevation* a wave obeying the same laws with any other order of wave?

Is the propagation of the tide-wave affected by *Local Winds?* and if so, in what manner?

These were questions to which, in the existing state of our knowledge of hydrodynamics, we had no grounds either dogmatical or empirical to form a reply, and it was therefore of importance to the advancement of the science of hydrodynamics that we should be able to fill up this *hiatus valde deflendus*. The question of the propagation possessed interest not only in a scientific view, but also from its practical importance; for it had been found in the earlier proceedings of this Association that the beautiful physical phenomena of *waves* were not only employed as agents to convey through the air the intimations of distant events to the sense of hearing, and to waft to the eye the exquisite sensations of light and colour, but were

likewise employed in the practical uses of every-day life, and took an important part in that commercial intercourse by means of which the comforts of life and the advancement of civilization are immediately promoted. It had been ascertained by former researches that the resistance of fluids to bodies moving through them is affected by an element which had not been formerly recognised; that the new element which had given rise to contradictory and apparently anomalous phenomena was a *wave* produced in the fluid by the moving body; and that this wave affected the amount of resistance, either positively or negatively, according as the velocity of the wave was greater or less than that of the moving body*. It became, therefore, an inquiry of theoretical and general interest, as well as of special and practical importance to the art of navigation, to determine with great accuracy the laws of this wave. It had already been satisfactorily established that the velocity of propagation of this wave was nearly that due to half the depth of the fluid, that this velocity was independent of the form of the generating solid, and of the generating velocity of the solid. But this law had not been extended to channels of different forms; neither had the conditions necessary to the existence of this wave, nor the nature of the mechanism by which its propagation takes place, been described and ascertained. This wave had been called the great solitary wave of the fluid, but its relation to other waves, and its identity or diversity, had not been determined.

It was also necessary to determine the nature and class of the waves with which we are most familiar, and which we see at the surface of water agitated by the wind, and which break on the shores of the sea. Do these belong to the previous class of waves, or do they not? their form and velocity have been thought to depend in some measure on the depth. Do they belong to the first class of waves, or are they a different class?

But the most important of all these investigations, both in relation to the advancement of physical science and to the practical value of their results, are probably those which refer to the propagation of the tide. The recent researches of Mr. Lubbock and Mr. Whewell, carried on in connexion with this Association and by its assistance, have conferred on the subject of the tides the interest of novelty as well as scientific value. Their researches have gone far towards removing the stigma

* *Researches in Hydrodynamics,* by John Scott Russell, Esq., M.A. F.R.S. *Edinburgh, Phil. Trans. R.S.E.,* 1836.

cast upon science by the imperfect state of this branch of knowledge. That the solar and lunar attractions produced some effect upon the tides, every one knew; but the problem was far from having been reduced into that condition in which it could be said that the phenomena of the heavens being given, the tides could be determined in magnitude and in time. So perfect, however, has this prediction lately become, that Mr. Lubbock has said that, considering how well theory agrees with observation, he is not sanguine that any material improvements in prediction will hereafter be made. And, indeed, this assurance appears to rest on valid grounds when it is considered that the tide tables which have resulted from his researches, and those of Mr. Whewell, give predictions whose errors are within the limits of the errors of observation.

But although the CELESTIAL MECHANISM of the tides has been thus perfectly analysed and explained, there remain a great variety of considerations relating to the propagation of tides along the surface of the globe which are as yet unexplained; these constitute the TERRESTRIAL MECHANISM of the tides. It is in the *generation* only of the tide that the solar and lunar attraction produce their effects: over the subsequent *propagation* of them, they exercise little or no influence. It is not until 50 or 60 hours after their creation that the tides reach our shores, having moved in the interval in every possible direction, and with every velocity from 100 to 10 miles an hour. This moving elevation of fluid may be conveniently designated a *wave*, and its history will be the history of the *tidal wave*; but to confer upon it the name of wave does not imply that its laws are those which belong to any other similar elevation with which we are acquainted. It was necessary to investigate the nature of this tide wave—to examine the hydrodynamical mechanism by which it is transferred from one place to another,—to determine the laws which regulate its form and its velocity—to ascertain if any relations exist between the form and dimensions of its bed, and its own form and rate of transference. These and many similar points were still unknown. Laplace has said, in speaking of these points, "les circonstances dont elles dependent, ne sont pas connues." Mr. Lubbock, in reference to the fluctuation of the establishment, says, "this perplexing fluctuation presents an insuperable obstacle to extreme accuracy in tide predictions until it can be explained; at present we are only left to conjecture respecting the cause." And similar sentiments are expressed by Mr. Whewell in the seventh series of his researches on the tides,

read on the 7th March, 1837. He observes, "I cannot conclude this paper without again pointing out that a great number of curious facts in fluid motion are established by these tide researches, of which it may be hoped that the theory of hydrodynamics will one day be able to render a reason." It was, therefore, necessary to investigate the subject of the terrestrial mechanism of the tides, that is, to determine the nature of the mechanism by which this tide wave is transferred from one part of the waters of a given channel to another. At the meeting of the Association at Bristol, Mr. Whewell had expressed his opinion that the great primary wave of Mr. Russell and the tidal wave would be identified.

The effect of wind upon the propagation of the tide wave was also a subject of importance. The magnitude of the tide is admitted generally to be affected by it in some way, but it is matter of doubt, whether the time of the tide, or rather the velocity of the tide wave, is at all affected. M. Daussy denies the existence of such an effect in the French observations, while it has been found by Mr. Lubbock in the London tides. It was necessary to determine this point with great accuracy.

Besides their direct and theoretical use, there was another point of some importance in these researches concerning the tide wave, viz., that if the tide wave should be found to obey the law of the great primary wave of fluid, we should be put in possession of the principles on which the improvement of tidal rivers might be effected.

Method of Inquiry.—The following order was adopted by the Committee in the means by which they endeavoured to carry on the inquiry with which they were entrusted:

The observations on the nature of the tide wave were those which it was important to obtain in the first place, as they required peculiar facilities which were not likely to be readily found.

Fortunately it occurred to one of the Committee that the river Dee in Cheshire was peculiarly suitable to their purpose. It was their object to determine whether the same law which regulated the propagation of the wave previously examined by Mr. Russell in experimental canals, was followed by the tide wave in its propagation, or whether the velocity of the tide wave were proportional to a certain depth in a certain form of channel. It was necessary for this purpose that a channel of uniform dimensions should be obtained which could be easily measured, and which should possess a tidal wave capable of being easily observed. Now it happened that the river Dee is,

in part of its channel, tolerably regular, having been formed artificially through a considerable part of its length; it was thought likely to answer the purpose.

In the month of September Mr. Russell visited Cheshire for the purpose of instituting the observations. He found the river more perfectly suitable than could have been anticipated. For more than five miles the channel of the river is perfectly straight, of a depth and width nearly uniform, inclosed between banks that are even and well kept, and that have everywhere the same slope, while the bottom has the slight declivity of 10 inches per mile. Along this channel the tide rolls with a moderate velocity, sometimes marked by a crested surge, and sometimes commencing by a motion hardly perceptible, and here it is inclosed by banks so high as to protect the wave most perfectly from the action of the wind from every point except two.

The channel of the river was measured and sounded with great care, and observations of its tidal wave will be found in this report. The form of the tide wave is given in plate (VI.).

The observations on the Dee having furnished data for the determination of the law of the propagation of the tidal wave in a given regular channel, it was only necessary further to ascertain the nature of its motion in a channel of a less regular form, and to determine the effect of the wind upon it. But the difficulty in this case was enhanced by the circumstance that a most minute and expensive survey would be required to determine the figure of such a channel with the accuracy necessary to furnish data for calculation. In this however the Committee were again fortunate. The River and Frith of Clyde on the West of Scotland presents a long and varied tidal channel which has all the variety of form necessary for such an investigation. The navigation of this river is under the management of a Board of Trustees, under whose superintendence it has been greatly improved, and who have been at great pains to determine its condition by very careful surveys. To that Board your Committee made application, and having the kind assistance of Sir Thomas Brisbane, who, as a former President of the Association, took a deep interest in forwarding its views, they succeeded in obtaining the effective cooperation of the Board of Trustees of the Clyde in carrying on an investigation which they considered of much importance to the navigation and future improvement of their own river.* Their excellent engineer, Mr. Logan, was immediately placed in communication with Mr. Russell, and

* The thanks of the British Association were afterwards tendered to the Trustees of the Clyde for their liberality.

instructed to afford every facility and assistance in his power; a most accurate survey of the river, with a longitudinal section and accurate transverse sections at every half mile were obtained, and a geometrical level of 18 miles was laid down with great precision. On this line were erected tide gauges of a peculiar construction, on which a small fraction of an inch could be read with ease even in a rough sea, and at a considerable distance from the instrument. These were placed at nine stations, and were simultaneously observed by careful observers every five minutes during at least one tide each day. The form and velocity of each tide wave were thus ascertained with the desired accuracy. Application was at the same time made to Captain Denham, a well-known member of this Association, who was kind enough to cause such observations of the corresponding high waters at the Liverpool Docks to be made as the nature of the situation would afford; and these, although less perfect than they would have been had the new arrangements for that purpose been completed which the interest taken by the British Association has been the means of originating, were yet sufficient to enable us to determine the tidal interval of the ports in the Clyde with Liverpool more accurately than hitherto. The observations after laborious corrections and reductions were all referred to mean solar line on the meridian of the observatory of the University of Glasgow, kindly granted by Professor Nicol for the purpose of regulating the chronometers.

The waves of the sea formed the subject of careful attention to your Committee. For this purpose one of them obtained the use of the Mermaid yacht, of Mr. Bogle, of Glasgow, kindly granted at the request of Mr. Allan, the secretary of the Northern yacht squadron, for the purpose of making the necessary observations at sea. The weather was rather unfavourable. The vessel encountered alternately severe gales and dead calms, which first drove her to seek shelter and then prevented her from leaving her asylum. By means however of these observations, and of others made in steam vessels crossing the Irish Channel, the results aimed at were obtained. This series was afterwards completed by observations made on the sea shore, by which the phenomena of surges have been perfectly explained.

The series was concluded by observations made in experimental reservoirs and channels. These were constructed of a variety of forms. The waves were generated in different ways and of very different species. An apparatus was contrived by which very great accuracy was obtained in the determination of velocity. A considerable series of these observations are given at the end of this report exactly as they were made, and

in such an extent of detail as to furnish any future theorist with data as minute as those he might obtain by individual observation. This branch of inquiry is however so extensive, that this report only gives the commencement of the series, the powers of the Committee having been extended during another year for continuing the inquiry.

General Results.—The following are nearly the general results of these inquiries in so far as they have hitherto been obtained.

1. The existence of a GREAT PRIMARY WAVE of fluid, differing in its origin, its phenomena, and its laws from the undulatory and oscillatory waves which alone had been investigated previous to the researches of Mr. Russell, has been confirmed and established.

2. The velocity of this wave in channels of uniform depth is independent of the breadth of the fluid, and equal to the velocity acquired by a heavy body falling freely by gravity through a height equal to half the depth of the fluid, reckoned from the top of the wave to the bottom of the channel.

3. The velocity of this primary wave is not affected by the velocity of impulse with which the wave has been originally generated, neither do its form or velocity appear to be derived in any way from the form of the generating body.

4. This wave has been found to differ from every other species of wave in the motion which is given to the individual particles of the fluid through which the wave is propagated. By the transit of the wave the particles of the fluid are raised from their places, transferred forwards in the direction of the motion of the wave, and permanently deposited at rest in a new place at a considerable distance from their original position. There is no retrogradation, no oscillation; the motion is all in the same direction, and the extent of the transference is equal throughout the whole depth. Hence this wave may be descriptively designated THE GREAT PRIMARY WAVE OF TRANSLATION. The motion of translation commences when the anterior surface of the wave is vertically over a given series of particles, it increases in velocity until the crest of the wave has come to be vertically above them, and from this moment the motion of translation is retarded, and the particles are left in a condition of perfect rest at the instant when the posterior surface of the wave has terminated its transit through the vertical plane in which they lie. This phenomenon has been verified up to depths of five feet.

5. The elementary form of the wave is cycloidal; when the height of the wave is small in proportion to its length the curve

is the prolate cycloid, and as the height of the wave increases the form approaches that of the common cycloid, becoming more and more cusped until at last it becomes exactly that of the common cycloid with a cusped summit; and if by any means the height be increased beyond this, the curve becomes the curtate cycloid, the summit assumes a form of unstable equilibrium, the summit totters, and falling over on one side forms a crested wave or breaking surge.

6. A wave is possible in forms of channel where the depth is not uniform throughout the whole depth. The full consideration of this subject is reserved for next report. It appears however that where the difference between the depth of the sides is considerable, one part of the wave will continue during the whole period of propagation in the act of breaking, so as to show that in these circumstances a continuous wave is impossible. In other cases the ridge of the wave rises so much higher on the shallower part of the fluid as to produce a given velocity without exceeding the limits of equilibrium, and in those cases the wave becomes possible, and the velocity appears to coincide closely with that which we obtain by supposing the wave resolved into vertical elements, each having the velocity due to the depth and then integrating.

For example, let the form of the channel be

$$y = m\,x^n$$

$$x\,\delta y = \text{vertical element of area}$$

$$\therefore \frac{1}{2} a^2 x = \text{the square of the velocity of the element,}$$

and

$$\frac{1}{2}\, a^2 x^2 \delta y = \text{the square of the velocity multiplied by wave,}$$

whence,

$$\int \frac{1}{2} a^2 x^2 \delta y = \int \frac{1}{2}\, a^2 x^2\, m\, n\, x^{n-1}\, \delta x$$

$$= \int \frac{1}{2}\, a^2\, m\, n\, x^{n+1}\, \delta x$$

$$= \frac{1}{2}\, a^2 \frac{m\,n}{n+2},\, x^{n+2} + \text{C}.$$

But since

$$\int x\,\delta y = \frac{m\,n}{m+n}\, x^{n+1}$$

$$\therefore v^2 = \frac{1}{2} a^2 \frac{n+1}{n+2} x$$

$$\text{and } v = a \left(\frac{1}{2} \frac{n+1}{n+2} x \right)^{\frac{1}{2}}$$

If $y = m x$

$$v = a \sqrt{\frac{1}{3} x}$$

If $y = m x^2$

$$v = a \sqrt{\frac{3}{8} x}, \text{ \&c.}$$

Hence in the rectangular channel the velocity being that of gravity due to half the depth.

In the sloping or triangular channel the velocity is that due to one-third of the greatest depth. In a parabolic channel the velocity is that due to three-eighths or three-tenths of the greatest depth according as the channel is convex or concave.

From the identity of this formula with that for the centre of gravity, it appears that the velocity of the great primary wave of translation of a fluid is that due to gravity acting through a height equal to the depth of the centre of gravity of the transverse section of the channel below the surface of the fluid.

7. The height of a wave may be indefinitely increased by propagation into a channel which becomes narrower in the form of a wedge, the increased height being nearly in the inverse ratio of the square root of the breadth.

8. If waves be propagated in a channel whose depth diminishes uniformly, the waves will break when their height above the surface of the level fluid becomes equal to the depth at the bottom below the surface.

9. The great waves of translation are reflected from surfaces at right angles to the direction of their motion without suffering any change but that of direction.

10. The great primary waves of translation cross each other without change of any kind in the same manner as the small oscillations produced on the surface of a pool by a falling stone.

11. The WAVES OF THE SEA are not of the first order—they belong to the *second or oscillatory order* of waves—they are partial displacements at the surface which do not extend to considerable depths, and are therefore totally different in character from the great waves of translation, in which the motion of displacement of the particles is uniform to the greatest depth. The displacement of the particles of the fluid in the waves of the sea is greatest at the surface and diminishes rapidly. There

are generally on the surface of the sea several coexistent classes of oscillations of varying direction and magnitude, which by their union give the surface an appearance of irregularity which does not exist in nature.

12. When waves of the sea approach a shore or come into shallow water, they become waves of translation, and obeying the laws already mentioned, always break when the depth of the water is not greater than their height above the level.

13. Waves at the surface of the sea do not move with the velocity due to the whole depth of the fluid: may they not move with the velocity due to that part which they do agitate, or to some given part of it?

14. A circumstance frequently observed when the waves break on the shore, has been satisfactorily accounted for by the examination of the constitution of the waves of the sea. It has been frequently observed that a certain wave is the largest of a series, and that these large waves occur periodically at equal intervals, so that sometimes every 3rd wave, every 7th, or every 9th wave is the largest. Now as there are almost always several coexistent series of waves, and as one of these is a long gentle "under swell," propagated to the shore from the deep sea in the distance, while the others are short and more superficial waves generated by a temporary breeze of reflections from a neighbouring shore; so it will follow that when the smaller waves are $\frac{1}{3}$, or $\frac{1}{7}$, or $\frac{1}{9}$th, or in any other given ratio to the length of longer ones, those waves in which the ridges of the two series are coincident, will be the periodical large waves; and if there be three systems of coexistent waves, or any greater number, their coincidences will give periodical large recurring waves, having maxima and minima of various orders.

15. The Tide Wave appears to be the only wave of the ocean which belongs to the first order, and appears to be identical with the great primary wave of translation; its velocity diminishes and increases with the depth of the fluid, and appears to approximate closely to the velocity due to half the depth of the fluid in the rectangular channel, and to a certain mean depth which is that of the centre of gravity of the section of the channel. It is, however, difficult to determine the limits within which the tide wave retains its unity; where portions of the same channel differ much in depth at points remote from each other, the tide waves appear to separate.

16. The tide appears to be a compound wave, one elementary wave bringing the first part of flood tide, another the high water, and so on; these move with different velocities according to the depth. On approaching shallow shores the anterior

tide waves move more slowly in the shallow water, while the posterior waves moving more rapidly, diminish the distance between successive waves. The tide wave becomes thus dislocated, its anterior surface rising more rapidly, and its posterior surface descending more slowly than in deep water.

17. A tidal bore is formed when the water is so shallow at low water that the first waves of flood tide move with a velocity so much less than that due to the succeeding part of the tidal wave, as to be overtaken by the subsequent waves, or wherever the tide rises so rapidly, and the water on the shore or in the river is so shallow that the height of the first wave of the tide is greater than the depth of the fluid at that place. Hence in deep water vessels are safe from the waves of rivers which injure those on the shore.

18. The identity of the tide wave, and of the great wave of translation, show the nature of certain variations in the establishment of ports situated on tidal rivers. Any change in the depth of the rivers produces a corresponding change on the interval between the moon's transit and the high water immediately succeeding. It appears from the observations in this report, that the mean time of high water has been rendered 37 minutes earlier than formerly by deepening a portion of about 12 miles in the channel of a tidal river, so that a tide wave which formerly travelled at the rate of 10 miles an hour, now travels at the rate of nearly 15 miles an hour.

19. It also appears that a large wave or a wave of high water of spring tides travels faster than a wave of high water of neap tides, showing that there is a variation on the establishment, or on the interval between the moon's transit and the succeeding high water, due to the depth of the fluid at high water, and which should, of course, enter as an element into the calculation of tide tables for an inland port derived from those of a port on the sea shore. The variation of the interval will vary with the square root of mean depth of the channel at high water.

These results give us principles, 1st, for the construction of canals; 2nd, for the navigation of canals; 3rd, for the improvement of tidal rivers; 4th, for the navigation of tidal rivers; 5th, for the improvement of tide tables.—See the Transactions of the Sections at the end of the volume.

First Series of Observations.

Experiments on Waves in Artificial Reservoirs.—As this portion of the experiments was made in continuation of a series of experiments in which Mr. Russell had been previously engaged, and of which he from time to time announced the results to the British Association at Dublin and at Bristol, and as these notices were omitted in the last volume of the Report, but promised by the Secretary to be included in the present one, it will be proper to state what had been brought to light in those experiments on waves previous to the appointment of this Committee.

At the Dublin meeting of the Association Mr. Russell stated that he had been induced to make a series of experiments on waves in certain circumstances, from having found that the resistance of fluids to the motion of floating bodies was very much affected by the phenomena of the waves generated in the fluid by the motion of these bodies; and that many of the imperfections of that part of hydrodynamical science which treats of the resistance of fluids, would be removed by an acquaintance with the laws of the motion of waves. One of the great instances of deficiency in our theoretical knowledge, when applied to practical uses, occurred in the question of the force required to give motion to a vessel in a confined channel, a canal, or a small river; in these cases a vessel at certain points of her progress encountered extreme resistance, and at other, still higher velocities, experienced diminutions of resistance equally extraordinary and anomalous. These facts had set at defiance all previous theory; but it was found that a knowledge of the laws of the generation and propagation of waves in a fluid was all that was required to solve these difficulties and to remove these anomalies. For this purpose he had undertaken a series of experiments on waves carried on during the years 1834 and 1835.

The WAVE which had been thus found to form so important an element in the resistance of fluids, was found to be a phenomenon of a very different nature from those waves which had previously occupied the attention of the physical investigator. This phenomenon presents itself as a SOLITARY PROGRESSIVE ELEVATION of the surface of a quiescent fluid, neither preceded nor followed by any secondary or successive phenomena, totally distinct from the *oscillatory waves*, and from such waves as the ripple on the surface of a lake agitated by the wind, and the concentric circular oscillations of a calm sheet of water into which a stone has been dropped, and from the waves which are

presented on the surface of an agitated sea. This wave presents simply the phenomenon of an elevation of fluid transferred from place to place of the fluid, finding the fluid perfectly at rest, and leaving it in an equally perfect state of equilibrium. Many philosophers have examined the theory of waves, but they all appear to have considered only the oscillatory, successive, and gregarious waves. NEWTON considered them as represented by the oscillations of a column of fluid in a bent tube, and assigned to them laws analogous to those of the pendulum; GRANESAUDE followed the theory of Newton; D'ALEMBERT adopted Newton's theory, and pursued this investigation considerably further; and LAGRANGE improved it by removing some former limitations inconsistent with the phenomena; LAPLACE formed a new theory, in which the oscillatory waves are supposed to be formed by immersing a solid of a given form in the fluid and suddenly withdrawing it; GERSTNER gives a very beautiful theory of waves, in which the observed phenomena of oscillatory waves of the larger class are very accurately represented; POISSON, CAUCHY, and FOURIER have discussed the mathematico-physical question of very minute oscillatory waves with so much success, as to represent some of the phenomena with considerable accuracy; and the results of these theoretical views have been examined very carefully in the experiments of BREMONTIER, FLAUGERGUES, BIDONE, and the WEBERS. But in none of these inquiries has the phenomenon of the solitary wave attracted any attention; and, indeed, so far from having been satisfactorily examined, its very existence does not appear ever to have been distinctly recognised.

This *solitary progressive elevation* appears to be the *wave of the first order*, and has been called by Mr. Russell the GREAT PRIMARY WAVE of the fluid. And its phenomena are of that invariable and decided character, which claim for it such a distinction.

The great primary wave was first observed by Mr. Russell in 1834. By the impulse of a vessel drawn by horses a considerable portion of fluid was raised above the level of the rest of the fluid in a channel of limited breadth and depth. The elevation thus formed was observed to assume a peculiar and regular shape extending across the whole breadth of the channel, and to propagate itself along the surface of the quiescent fluid with a velocity of nearly eight miles an hour; which velocity and form appeared to continue unchanged, although followed for about the distance of a mile.

The following experiments were made for the purpose of determining whether the velocity of this wave were not affected

by the initial velocity given to the fluid at its generation by the moving body. The velocity of genesis, or of the vessel by whose displacement the elevation of fluid was produced, is given in miles per hour, and the time occupied by the wave in describing 700 feet is given in seconds.

	Velocity of genesis.	Space described by the wave.	Interval of time.
(1.)	5 miles an hour	700 feet	62· seconds
(2.)	3 ——	700 —	61· —
(3.)	10 ——	700 —	61· —
(4.)	7 ——	700 —	62· —
(5.)	7 ——	700 —	62· —
(6.)	4 ——	700 —	61·5 —

From this it is manifest that the velocity of the propagation of the wave does not vary with the velocity of its genesis.

To determine whether the height of the wave produced any variation in its velocity, the following experiments were made:

	Height of the wave above the level.	Space described.	Interval.
(7.)	6·0 inches	700 feet	61·50 seconds
(8.)	5·0 —	700 —	61·75 —
(9.)	3·5 —	700 —	62·50 —
(10.)	2·0 —	700 —	63·50 —

It appears from these examples that, in a given reservoir of fluid, the higher wave moves more rapidly than the lower; and it was afterwards found that the increase of height was equivalent in its effect on the velocity to an equal addition to the depth of fluid in the reservoir.

To determine whether the depth of the fluid affected the velocity of the wave, the following experiments were made in the same channel filled to different depths:

	Depth of fluid.	Space described.	Velocity of wave.
(11.)	5·6 feet	486· feet	9·594 miles an hour
(12.)	3·4 —	150· —	7·086 ——

The former of these observations is exclusive of the height of the wave, and adding six inches to the depth of the fluid in this case, the height of the wave being already added to the depth in (12.), we find that the velocities are nearly proportional to the square roots of the depths, and are nearly equal to the velocities that would be acquired by a heavy body in falling through heights equal to half the depth of the fluid.

In the last case the channel was rectangular, and conse-

quently the depth of the fluid was uniform across the whole depth of the channel; it was next of importance to ascertain what law held in those cases where the depth diminished towards the edges of the channel. For this purpose two channels were selected having the greatest depths in their middle and diminishing towards the sides. The following are the results:

	Greatest depth in the middle of the channel.	Space described.	Velocity of wave.
(13.)	5·5 feet	1000 feet	7·84 miles an hour
(14.)	4·0 —	820 —	6·09 ——

In these instances the diminished depth at the sides has diminished the velocity of the wave below that due to the greatest depth in a ratio in the first example nearly of 9·5 to 7·8, and in the second of 7· to 6·. See Experiments (11) and (12).

The following three experiments are instructive as having been made on channels in which the maximum depth was nearly the same in all; but in (15) the depth remained constant to the side which was vertical. In (16) the sides had a slope of nearly 20°, and in (17) a slope of nearly 40°, so as to diminish the depth towards the sides.

	Maximum depth.	Form of channel.	Space described.	Velocity.
(15.)	5·6 feet	Rectangular	486 feet	9·59 miles
(16.)	5·5 —	Slope of 20°	2038 —	8·83 —
(17.)	5·5 —	Slope of 40°	1000 —	7·84 —

From these it is manifest that the depth of the channel, while it modifies the depth of the fluid, affects the velocity of the wave. It was not found that the breadth of the channel produced any similar effect.

The results obtained from the experiments of 1834 and 1835 were considered by the Association of sufficient novelty and importance to point out the propriety and advantage of instituting a fuller and more minute series of experiments concerning the nature of the wave, in which all its phenomena and laws should be determined with as much precision as possible.

The subjects of inquiry which immediately presented themselves were the following:

1. To determine whether different methods of generating the wave influence its subsequent phenomena.

2. To determine with accuracy the velocity of the wave in given circumstances.

3. To ascertain the form or forms of the wave.

4. To determine the manner in which the depth and breadth of the channel affect the velocity and form of the wave.

5. To determine the influence of form in the channel on the form and velocity of the wave.

6. To ascertain the nature of the mechanism by which the wave is propagated from one place to another; or to answer the question, What is the wave?

7. To ascertain the difference between *the primary wave* and waves of other descriptions.

8. To determine the effects of solid bodies or obstacles on the motion of waves, and the effect of waves on one another, and conversely—the effect of waves on solid bodies, either at rest or moving through them, immersed in them, or floating upon their surface.

9. To determine the effects of waves on one another.

For the purpose of obtaining some of these results with the requisite precision, there was provided the following

Experimental Apparatus.

Experimental reservoir.—A rectangular reservoir, formed with much precision, was provided for the purpose of containing the fluid to be made the subject of experiment. Its sides were supported by strong brackets, and the whole was raised on a strong frame to a height convenient for experiment; the whole length of the reservoir was 20 feet precisely, an additional length of 7·3 inches having been reserved to form a generating chamber in connexion with the reservoir. The dimensions of the reservoir are,

Length of experimental reservoir . . .	20 feet
Breadth of experimental reservoir . . .	1 foot.

The bottom of the reservoir was placed with care in the horizontal plane, so that it could be filled and emptied conveniently. The reservoir is represented in Plate I., fig. 1. A is the transverse section, B and D are longitudinal sections of the levels of the reservoir.

Method of determining the velocity.—A channel of great length may appear at first sight more suitable to the determination of velocity than the comparatively short one here employed, whose whole length was traversed by some of the waves in less than five seconds; and it would have been preferable for that purpose had not the method of reflection been employed, by which all the advantages of that method when employed in the repeating circle and other instruments are obtained for the diminution of errors of observation, and by which also the pro-

bability in favour of accuracy in the result is elevated to the region of certainty. It was found that when a smooth plane surface, of sufficient rigidity, was immoveably fixed at the end of the channel, at right angles to the direction of the wave's transmission, the wave was thereby reflected without sensible change in its form, magnitude, or velocity. Two such reflecting surfaces being placed at opposite ends of the reservoir, it was found that the wave might be reflected from one end to the other over successive spaces of 20 feet, and thus brought repeatedly to the same points of observation. In this way the same wave was observed during so many as 60 successive transits after 60 successive reflections, having thus passed over a course equal in length to 1200 feet, and occupying an interval of 320 seconds, giving the power of observing it 60 times in its transit past a given point. It was thus brought under the eye of three observers at three different parts of the reservoir during a single transit. The whole internal surface of the reservoir was accurately divided into feet, inches, and minuter divisions.

Means of observing the transit.—To observe the instant of the transit of a wave past a given point is a matter of some difficulty, especially when the wave is long and flat. A wave one-tenth of an inch high and three feet long is scarcely sensible to the eye until its vertex has passed; its commencement and end are perfectly insensible, and its summit so flat that it is impossible directly to observe its place with precision. To obviate these difficulties, the following apparatus was provided. A plane mirror, M, (Fig. 2. Plate 1.) was raised on a frame to a height of four feet above the surface of the water. On this mirror the image, I, of a bright flame was thrown, and the mirror was adjusted so as to reflect this image upon the surface of the water (at W). A second mirror (m) was placed over this second image, so as to intercept the rays reflected from the surface of the water, and to return them finally through an eyepiece to the observer. The path of the ray was preserved during the whole of its extent in a plane at right angles to the direction of the motion of the wave. Parallax in observation was avoided by a micrometer wire in the eye-piece, which was kept in coincidence with an opaque line passed through the image at M and so reflected in m, and with a line of division, D, seen directly without reflection past the edge of the mirror m. The observer was thus enabled to compare the place of the centre of the reflected image by coincidence with fixed lines. When perfectly at rest the coincidence was perfect. When the centre of the wave was at W^{II}, figs. 2 and 3, the rays of light also reflected from a plane surface, perfectly horizontal, presented the

same coincidence; but when the anterior part of the wave $W^{I.}$, figs. 2 and 3, was that on which the rays fell, the image was carried in the direction of the motion; and, on the other hand, when the posterior surface of the wave reflected the image, it was transferred to the other side, as in the point $W^{III.}$ When, therefore, the transit of a wave took place, the following phenomena presented themselves to the observer. The image continued at rest, as seen in fig. 3, until the approach of the wave; from the instant at which the transit began until the instant of the passage of the crest of the wave, the image appeared on the anterior side of the wire, as in fig. 4; but during the remainder of the transit, the image was found on the posterior side of the wire, as in fig. 5; and therefore the instant of the transit of the crest of the wave across the line was also the instant of the passage of the image from one side to the other across the wire: now, as the whole time of the transit did not amount to a second, this instant was given with the required precision, and although the elevation of the surface was not in many cases perceptible to the eye, the transit of the image was perfectly satisfactory.

For obtaining the dimensions of the wave with precision, various expedients were resorted to; there were provided glass tubes (gauges or *indices*) communicating with the channel at different depths; they are represented in fig. 6. The centre of each tube opens into the side of the reservoir at successive inches of its height, and after continuing horizontally for a certain space, is turned up vertically, and rises above the level of the water; the tubes thus become filled, and the water in each tube being tinged with colouring matter becomes distinctly visible, so that the variations of height are read with ease and precision on the graduated scale behind the tubes to hundredths of an inch. For a very elegant method of ascertaining the length of the wave with precision, Mr. Russell is indebted to Professor STEVELLY of Belfast, who suggested that fine points, similar to those used in the standard cistern barometers, should be applied to the surface of the water, so as to show by the instant of their submersion in the fluid, or emergence from it, the origin and end of the wave. This method was found to possess much precision; the phenomena of capillary attraction mark the instants of contact and separation with vividness, by the reflection of rays of light from the concave surface of the fluid raised around the point, and their disappearance on separation. The contact of this point with its image in the water was also a phenomenon marking the place of the surface of the fluid with minute accuracy. When the two points, placed at the beginning and end of the wave, showed the phenomena of

immersion and emergence at the same instant, their distance was equal to the length of the wave. It was, however, necessary to have some means of bringing both points under the eye at the same instant, in order to determine with accuracy the coincidence of contact in both cases; the arrangements are given in fig. 7. P and P are points in contact with the surface of the fluid at the extremities of a wave; rays of light from them are reflected by the mirrors p and p to the eye at O, and are thus observed simultaneously. By these means, the points being removed further apart, or brought nearer, until the contact became simultaneous, and the distance of the points equal to the length of the waves, the height of the wave was determined by the glass indices in fig. 6.

Apparatus for generating the Waves.—Generating reservoir A. fig. 8, consisted of a continuation of the experimental reservoir A, B, D, of fig. 1, which was separated from it or connected with it by means of a sluice; so that by filling the generating reservoir with water to a higher level than the experimental reservoir while the sluice was closed, on raising it the water descended, producing a wave, of which the volume was known. The area of the horizontal section of the generating reservoir is 76·27 square inches, its length being 6·33 inches in the direction of the motion of the wave, and 12·05 inches its breadth at right angles to this; the detached generating chamber B, fig. 9, was a rectangular parallelopipedon, open at top and bottom, and so accurately fitted to the bottom of the reservoir as, when resting on it, to be capable of containing water to any height, but on raising it from the bottom by which it had been thus temporarily closed, the fluid descended, producing a wave of given volume. The area of the horizontal section of the chamber is 68·32 inches, being 6·1 inches long and 11·2 inches wide. A solid parallelopipedon, C. fig. 10, was used to generate waves, by protruding it to a given depth in the fluid; the area of its horizontal section being 88·32 inches, and its dimensions 24·0, 12·05, and 7·33 inches. Another detached generating chamber, D., was 2·98 inches, being 11·92 inches broad and 24· inches deep, being an area of 35·52 square inches in its horizontal section. In those cases where volume of the wave was not of importance, the wave was produced by the impulse of a flat surface pressed horizontally on the fluid.

Analysis of Experiments.—The original experiments are themselves given at the end of this paper, for the purpose of enabling any one who may be disposed to make use of them for any future purpose, either of framing or testing a theory, to

make use of them much in the same way as if he had himself made the experiments. The wave having been generated was first observed in the glass index, fig. 6, placed near to the generating reservoir; then it passed under the transit station where its transit was observed, and the time registered either by one or two observers, and then its height was cleared in another glass index near the other reservoir; the wave having undergone the first reflection was returned, and the same observations were repeated during a number of successive reflections. See Experiments page 465—491.

The collection of tables at the end of this report gives the history of a series of waves in which these phenomena are carefully recorded.

Explanation of Tables.—For the sake of ready reference, there is given at the beginning of each table (see Wave I.) the approximate depth of the fluid, and the date of experiment, thus:

2d Aug. 1837. Wave I. Depth, 4 inches.

The next line contains the mode of generation, written thus:

Created by reservoir A. Volume of added fluid = 153·5 inches.

The reservoir A, fig. 1, Plate I., the detached chamber B, fig. 9, the solid parallelopipedon C, fig. 10, and chamber D, have already been described, and are successively referred to in the manner now stated; and in Wave IX. for example, the means of generation was the flat sluice in fig. 8, held in the hand, passed down to the bottom of the fluid, and moved horizontally so as to displace the fluid from the reservoir A.

The method of observing is next given, as for example in Wave I.

Transits observed directly at index, and without reflection—

when the unassisted eye of the observer detected by inspection the transit of the ridge of the wave passing the place of the indices at γ. fig. 6; but in other cases the eye was arrested by the reflected image in the transit apparatus already described, figs. 2, 3, 4, and 5, as for example in Wave V., where we have

Transits observed by the reflected image at the central station.

The next line gives the depth of the fluid in the channel, previous to the commencement of the experiment, first of all as

directly observed in the glass indices, figure 6, on the scale of which the deviation from approximate depth, already given at the head, (Depth, 4 inches,) is read off with the appropriate sign + or —; and the mean depth of the fluid having been already compared by direct experiment with the scale of the index, and a correction for error of scale applied, the true result is given at the end as the mean depth of the fluid when at rest, freed from instrumental error, thus:

Statical level observed at $\left\{ \begin{array}{l} \gamma = -0{\cdot}05 \\ \delta = -0{\cdot}01 \end{array} \right\}$ corrected statical depth=3·942 inches.

In the table of the observations, *column* A gives the number of feet passed over by the wave, reckoning from the instant at which the first observation of time in *column* B was made on either or both of the chronometers a and β. In *column* C are given the readings of the index γ at that end of the reservoir where the wave was generated, and from which the observations are begun, and of the index δ placed towards the other end of the reservoir. In *column* D the observations of column C have been freed from the error of the index scale, so as to represent the true height of the ridge of the wave above the statical level of the fluid; and in *column* E the true height of the wave has been added to the statical depth of the fluid, so as to give the whole depth reckoned from the ridge of the wave to the bottom of the reservoir.

The observations were made in the following manner. The wave having been generated, was generally allowed to traverse the whole length of the reservoir, and return to γ before commencing the observations of time and space; this was done for the purpose of allowing the wave to assume its determinate form, which it did not generally acquire until it had remained for some time unaffected by external impulse; and this delay also allowed the secondary oscillations of the fluid to disappear. On the return of the wave to γ its height was carefully observed; after passing γ its transit past the central station was assumed as the zero for time, its height was observed at δ, and once more on its return to γ, so that the interval between the observations was an interval due to 20 feet or 40 feet, according as the observations were made on successive or alternate transits; the successive transits being used when the velocity was small, and the alternate ones when the velocity was such as not to afford sufficient intervals for observing and noting with composure.

The intervals between the transits were obtained with considerable precision, as may be gathered from the following

observations made by independent observers.—See Wave XLV.

Chronometer α.	Chronometer β.	Difference of interval.	Chronometer α.	Chronometer β.	Difference of interval.
0·0	0·0	0·0	89·00	89·5	0·00
9·75	9·5	– 0·25	99·50	100·0	0·00
19·50	19·0	– 0·25	110·00	110·5	0·00
28·50	29·0	0·00	120·50	121·0	0·00
38·50	39·0	0·00	131·00	131·5	0·00
48·50	49·0	0·00	141·50	142·0	0·00
58·50	59·0	0·00	151·50	152·5	– 0·50
68·50	69·0	0·00	162·50	163·0	+ 0·50
79·00	79·5	0·00	173·00	173·5	0·00

One of the first objects of inquiry was, to determine whether there existed any important difference in the phenomena of waves generated by different methods and by bodies of different forms, or to ascertain whether a wave being given in height and depth, the phenomena were the same and independent of the source from which it had been originally derived. To give the value of the comparison, we shall collate the history of four waves generated by four different methods, and very nearly of the same magnitude and in the same depth of fluid.

WAVE XIX. Generated by protrusion of solid C. Depth = 3·95 in.		WAVE XV. Generated from chamber B. Depth = 3·87 in.		WAVE VIII. Generated by simple impulsion. Depth = 4·15 in.		WAVE VII. Generated from reservoir A. Depth = 4·07 in.	
Sec.	In.	Sec.	In.	Sec.	In.	Sec.	In.
10·5	5·40	...	...	...	...	...	...
10·5	5·22	...	5·30	...	5·10	...	...
10·5	5·15	10·0	5·32	11·0	5·02	...	...
10·5	5·02	10·5	5·20	11·0	4·95	...	...
10·5	4·83	11·0	5·03	11·5	4·85	...	...
12·0	4·76	11·0	4·96	11·5	4·75	...	...
12·0	4·67	11·5	4·68	11·0	4·69	...	...
11·5	4·58	11·0	4·60	11·5	4·61	...	4·62
11·5	4·55	12·0	4·55	12·0	4·55	...	4·58
11·5	4·50	12·0	4·43	11·0	4·48	11·5	4·52
11·5	4·42	11·0	4·36	12·5	4·43	11·5	4·46
				11·5	4·40	11·5	4·40
11·13	4·82	11·11	4·84	11·5	4·37	11·5	4·35
				12·5	4·36	12·0	4·27
				12·0	4·33	12·0	4·26
				12·0	4·29	12·0	4·26
				11·60	4·66	11·70	4·41

These columns contain the intervals of description of successive spaces of 40 feet each, with the mean depth reckoned from

the top of the wave, ascertained from the mean of three observations in each distance of 40 feet. The waves were generated by four different methods, the depth of the fluid and the height of the wave are different in each; so that on comparing them together, we have to take into consideration the variations of the conditions. Now between the mean interval of the successive transits in XIX. and XV., the difference is only two-hundredth parts of a second, and between the mean height of the wave in the former case, and in the latter, there is a corresponding difference with the same sign, amounting to two-hundredth parts of an inch—between VIII. and VII. the same coincidence exists. The same harmony runs through that whole series of observations from Wave I. to Wave XXVI., and appears to warrant the conclusion, that *between waves of this order, generated in very different methods, no sensible difference in the law of propagation can be distinguished.* In the remaining series of observations, the protrusion of solid C was the method generally adopted for generating the waves, as it was found convenient and precise. Various other methods, such as suspending the fluid by atmospheric pressure and the immergence of bodies of different forms, were tried, without sensible difference on the result.

Waves were then generated in different depths of the fluid, and having different heights, for the purpose of determining the velocity due to them with all the precision which the method was capable of affording. The three columns of figures which follow, are a short table of results, and in a fourth column are given a few theoretical numbers, representing the height due to half the depth of the fluid, reckoning from the ridge of the wave. The first of these columns gives the total depth reckoned from the top of the wave, the second column is the height of the wave itself above the quiescent fluid, and the third the observed velocity.

Total depth.	Height of the wave.	Velocity observed.	Velocity due to half the depth.
1·00	...	...	1·636
1·05	0·05	1·64	...
1·30	0·15	1·84	...
2·00	...	...	2·314
2·19	0·29	2·30	...
3·00	...	...	2·834
3·10	0·16	2·87	...
3·23	0·15	2·99	...
4·00	...	...	3·273
4·00	0·19	3·33	...
4·08	0·13	3·24	...
4·20	0·13	3·33	...
4·31	0·24	3·40	...
5·00	...	...	3·701
5·20	0·10	3·73	...
5·25	0·15	3·72	...
6·00	...	...	4·008
6·40	0·15	4·04	...
6·47	0·27	4·14	...
6·74	0·54	4·32	...
7·00	...	...	4·333
7·33	0·29	4·39	...
7·44	0·40	4·44	...
8 00	...	...	4·628

Table of Experiments in Rectangular Channel.

Reference to original observations.	Total depth from the ridge of the waves.	Height of the wave.	Time occupied in describing space in next column.	Space described.	Velocity of wave in feet per sec.
	Inches.	Inches.	Seconds.	Feet.	
XXIX. ...	1·05	·05	36·5	60·0	1·64
XXVII. ...	1·10	1·10	23·5	40·0	1·70
XXVIII. ..	1·20	·20	22·7	40·0	1·76
XXXIII. .	1·30	·15	22·0	40·0	1·81
XXXV. ...	1·62	·32	29·0	60·0	2·06
XXXVI. ..	2·19	·29	34·7	80·0	2·30
XLI.	3·09	·15	27·5	80·0	2·90
XL.	3·11	·17	14·0	40·0	2·85
XLI.	3·16	·22	21·0	60·0	2·71
XL.	3·20	·26	22·0	80·0	2·72
XLI.	3·23	·29	27·0	80·0	2·96
XXVI. ...	3·23	·15	69·5	200·0	2·99
XXVI. ...	3·32	·24	27·0	80·0	2·96
XXXVIII.	3·35	·35	27·0	80·0	2·96
XL.	3·38	·44	19·5	60·0	3·07
XLI.	3·41	·47	20·0	60·0	3·00
XV.	3·40	·32	27·0	80·0	2·96
XXVI. ...	3·50	·44	26·0	80·0	3·08

Reference to original observations.	Total depth from the ridge of the wave.	Height of the wave.	Time occupied in describing space in next column.	Space described.	Velocity of wave in feet per sec.
	Inches.	Inches.	Seconds.	Feet.	
XXXVII..	3·50	·50	19·0	60·0	3·15
XXXIX. .	3·60	·66	13·0	40·0	3·07
XXV.......	3·61	·53	26·5	80·0	3 02
XL.	3·69	·75	18·5	60·0	3 24
XXVI. ...	3·81	·73	25·0	80·0	3·20
XXXVIII.	3·81	·81	18·5	60·0	3·24
XXXIX. .	3·84	·92	18·5	60·0	3·24
XL.	3·90	·96	12·0	40·0	3·33
XXV.......	3·97	·81	24·5	80·0	3·22
II.	4·00	·19	36·0	120·0	3·33
IV.........	4·08	·13	74·0	240·0	3·24
II.	4·12	·31	24·2	80·0	3·30
IV..........	4·15	·34	25 0	80·0	3·20
VII.	4·20	·13	36·0	120·0	3·33
IV..........	4·25	·45	47·7	160·0	3·35
VII.	4·31	·24	46·75	160·0	3·40
II.	4·40	·59	23·5	80 0	3·40
IV..........	4·45	·64	35·5	120 0	3·38
VII.	4·49	·42	34·75	120·0	3·46
XIX.	4·51	·56	42·5	160·0	3·76
XV.	4·61	·74	22·5	80·0	3·52
XIX.	4·75	·80	23·0	80·0	
XLV.......	5·20	·10	32·0	120·0	3·73 3·77 3·80
XV.	5·21	1·34	31·5	120·0	
XLV.......	5·25	·15	43 0	160·0	3·72
XLV.......	5·35	·25	21·2	80·0	3·77
XLIII. ...	5·40	·36	32·0	120·0	3·75
XLV.......	5·50	·40	21·0	80·0	3·80
XLIII. ...	5·61	·57	39·5	160·0	4·05
XLVI. ...	5·80	·70	20·0	80·0	4·00
XLIII. ...	5·82	·78	30·5	120·0	3 93
XLV.......	5.82	·72	20·5	80·0	3·90
XLIII. ...	6·15	1·05	19·0	80·0	4·21
XLVI. ...	6·15	1·13	19·0	80·0	4 21
XLV.......	6·26	1·16	29·5	120·0	4·08
XLV.......	6·40	1 30	28·7	120·0	4·18
L.	6·40	·15	49·5	200·0	4·04
XLIX. ...	6·47	·27	29·0	120·0	4·14
XLIX. ...	6·54	·34	39·5	160·0	4·05
L.	6·56	·31	39·0	160·0	4·10
XLIX. ...	6·65	·45	29·0	120·0	4·14
XLVI. ...	6·69	1·59	18·5	80·0	4·32
XLVIII....	6·74	0·54	18·5	80·0	4·32
L.	6·75	0·50	48·5	200·0	4·13
L.	6·86	·61	38·0	160·0	4·21
XLVIII....	6·90	·70	37·5	160·0	4·29
XLIX. ...	7·20	1·0	37·0	160·0	4·32
LIII.	7·42	·38	45·5	200·0	4·40

Reference to original observations.	Total depth from the ridge of the wave.	Height of the wave.	Time occupied in describing space in next column.	Space described.	Velocity of wave in feet per sec.
	Inches.	Inches.	Seconds.	Feet.	
LV.	7·33	·29	73·0	320·0	4·39
LV.	7·44	·40	36·0	160·0	4·44
LI.	7·68	·64	28·0	120·0	4·37
LIII.	7·70	·66	27·0	120·0	4·43
XLVIII....	7·74	1·54	26·5	120·0	4·44
LV..........	7·75	·71	35·5	160·0	
LIII.	7·79	·75	27·0	120·0	4·43
LII.	7·82	·78	26·5	120·0	4·53
LI.	7·84	·80	27·0	120·0	4·43
LV..........	7·87	·83	26·5	120·0	4·53
LII.	8·00	·78	26·5	120·0	4·53

Observations on the influence of the form of the channel on the propagation of the wave extend from Wave LVI. to Wave CXLIX., at the end of the report.

The triangular channel H was of the form given in Plate III., fig. 2, its depth having varied by the quantity of water poured in, its vertex undermost, one side vertical and the other inclined to the horizon at an angle whose radius is to its tangent as 3 to 2. In all these experiments the wave was observed to be low and flat on the deep side of the channel, while it remained high and cusped on the shallow side; it was also long on the deep side, and diminished in length uniformly with the diminution in depth. The following table contains an analysis of the experiments in the channel H. The first column refers to the individual wave made the subject of experiment, so that it may be referred to in its place at the end of the report. The second column contains the total depth reckoned from the top of the wave on the deep side. The third column gives the height of the wave. The fourth column contains the number of seconds employed in describing the number of feet given in the fifth column; and the last column is the resulting velocity.

It should be recollected, before proceeding to compare these observations with any formula, that the attraction of the sides at the bottom of the channel in the acute angle of the channel must be considered as having fixed a portion of the fluid which was not affected by the motion of the wave, and which should therefore be subtracted from the effective depth.

Analysis of Observations of Waves in the Triangular Channel H., Plate III., fig. 2.

Reference to original observations.	Total depth from the ridge of the wave.	Height of the wave.	Time occupied in describing space in next column.	Space described.	Velocity of wave in feet per sec.
	Inches.	Inches.	Seconds.	Feet.	
LVIII. ...	4·15	·15	36·5	80·	2·19
LIII. ...... LIX.	4·23	·22	33·0	80·	2·42
LVI. ...... LX.	4·32	·31	31·0	75·5	2·43
LVII. ...... LVIII. ... LIX.	4·38	·37	47·0	115·5	2·46
LVIII. ...	4·71	·70	13·5	35·5	2·62
LX. ...... LXI.	4·81	·80	29·5	75·5	2·57
LXIX. ...	4·86	·85	14·0	35·5	2·53
LXII.......	5·29	·18	31·0	80·0	2·58
LXV.......	5·44	·33	45·5	120·0	2·63
LXIII. ...	5·55	·44	58·0	160·0	2·75
LXII.......	5·59	·48	30·0	80·0	2·66
LXV.......	5·99	·88	12·0	35·5	2·95
LXIII. ... LXIV. ...	6·01	·90	24·5	71·0	2·89
LXVI. ...	6·18	·14	28·0	80·0	2·85
LXVII. ... LXVIII....	6·26	·21	55·5	160·0	2·88
LXVI. ...	6·38	·34	14·0	40·0	2·85
LXII.......	6·44	1·33	12·0	35·5	2·95
LXVII. ...	6·52	·48	26·5	80·0	3·02
LXVI. ... LXVIII...	6·78	·74	35·0	111·0	3·17
LXX.......	7·10	·60	26·5	80·0	3·02
LXXV. ...	7·12	·08	39·5	120·0	3·03
LXXII. ... LXXI. ...	7·15	·11	78·5	240·0	3·05
LXXIII... LXXIV....	7·16	·12	52·5	160·0	3·04
LXXI. ...	7·21	·17	26·5	80·0	3·02
LXXIII...	7·36	·32	26·5	80·0	3·02
LXXV. ...	7·51	·47	25·0	80·0	3·20
LXXIV....	7·53	·47	24·0	80·0	3·33

The triangular channel K was of the form given in Plate III., fig. 3, the breadth at the surface of the water being 12 inches, the depth 4 inches to 0. It was observed that during the whole of the experiments the wave was long and low on the deep side; short and pointed, and considerably higher and continually breaking, on the shallow side, so as to leave behind a long train of secondary waves.

The trapezoidal channel L was formed by the addition of a rectangular portion, 1 inch deep, to channel K. See Plate III. fig. 4.

The trapezoidal channel M was formed by the addition of a rectangular portion, 1 inch deep, to channel L.

Analysis of Observations of Waves in the Channels K, L, M.

Reference to original observations.	Total depth from the ridge of the wave.	Height of the wave.	Time occupied in describing space in next column.	Space described.	Velocity of wave in feet per sec.
K					
	Inches.	Inches.	Seconds.	Feet.	
LXXIX...	4·14	·10	19·5	40·0	2·05
LXXVIII.	4·21	·17	17·5	40·0	2·28
LXXVI.... } LXXVII.. }	4·42	·37	40·75	102·2	2·50
LXXVIII. } LXXIX... }	4·46	·41	31·7	82·2	2·60
LXXVIII.	5·31	1·27	5·0	14·6	2·92
L					
LXXXV..	5·24	·24	12·5	40·0	3·20
LXXXII..	5·42	·42	13·5	40·0	3·00
LXXXI... } LXXXIV. } LXXXV.. }	5·53	·53	42·0	120·0	2·90
LXXXIV.	5·68	·68	13·5	41·1	3·04
LXXXIII.	5·70	·70	12·7	41·1	3·23
LXXXII..	5·77	·77	20·0	61·1	3·05
LXXXI... } LXXXIV. }	6·41	1·41	8·5	29·2	3·43
LXXXII..	6·47	1·47	4·5	14·6	3·24
LXXXIII.	6·67	1·67	4·0	14·6	3·65
LXXXV..	6·92	1·92	4·0	14·6	3·65
M					
XC. ...... } XCIII. ... }	6·41	·40	13·0	40·0	3·08
XC. ...... } XCIII. ... }	6·87	·86	11·4	40·0	3·50
XC. ...... } XCIII. ... }	7·43	1·42	9·25	35·7	3·86

The wedge-formed channel was of uniform depth, twelve inches wide at the broad end, and tapering to an edge at the

other; the wave on entering the channel at A was observed; its height was again taken at B, when it had advanced half the length of the channel, and had been diminished one half in breadth; and at C, after having passed along three-fourths of the length of the channel, the height was again observed. The wave was observed breaking invariably at the height of about 3·6 inches above the level of the fluid; and the distance from D, the end of the channel, when it broke, is given with the sign minus prefixed. On entering the channel the wave was low, but gradually increased as it reached the narrower parts of the channel, becoming acuminated; and at last having gained the cusped cycloidal form, broke at the crest, and passed into the centre angle of the wedge, when it rose suddenly over the sides of the channel in a sharp vertical *jet d'eau*. A table of these experiments is given at the end, comprehending Waves XCIV.—CVI.

The sloping channel, Plate II. fig. 6, was formed to imitate a sloping sea beach; its slope rose 1 in 51. The wave entered the deep end at a given height, then gradually became more acuminated, formed a cycloidal cusp, and broke. Its height on entering, its height when breaking, and the place at which it broke were observed and are given in the observations at the end from Wave CVII. to CXXXII. The numbers in the last column are the depths corresponding to the place of breaking observed in the preceding column, and this table shows that the depth at breaking corresponds with remarkable accuracy to the height of the wave.

A considerable number of observations were made upon the translation of the particles of the fluid during the transit of a wave, but the results are not of a numerical character, being all comprehended in the general expression that the translation of the particles takes place wholly in the direction of the motion of the wave; that it is of equal extent from the surface to the bottom of the channel, that it is permanent, that the particles which were in the same vertical plane previous to translation are still so after translation. This is not the case in other species of waves; the particles oscillate in opposite directions with an alternating motion.

Experiments were also made on waves formed by the removal of a solid body from a quiescent fluid; these are called negative waves, but the investigation of them has not yet been completed.

Second Series of Observations.

On the Waves of the Sea.—Are the waves on the surface of the sea, when it is agitated by the wind, of the same nature with the waves which have already been examined by experiment?

Does their velocity depend on the depth of the fluid? Is their form cycloidal? What is the cause of their breaking on the shore? And what law is observed in their breaking? Why do waves in any circumstances break? What is a breaker? These are some of the questions which the Committee have examined, and their results are of importance to theory and to navigation.

The Committee obtained for the purpose of their observations on the waves of the sea the use of one of the yachts of the Royal Northern Yacht Squadron, which was kindly granted by her proprietor, James Bogle, Jun., Esq., at the request of the secretary. The Mermaid was an excellent sea vessel, but the weather was unfortunate; she was alternately becalmed and bestormed; one day driven into harbour for refuge and the next day prevented by calms from leaving harbour. Out of eight days occupied in this way not more than one was favourable to observation. By subsequently crossing the Irish Channel in steam-vessels one or two observations of a sufficiently accurate nature were obtained.

From these observations it appears to be established that the velocity of the waves at the surface of the deep water is not a direct function of the depth.

In a depth of 50 to 60 fathoms the velocity was 13·5 miles an hour.
In a depth of 53 fathoms the velocity observed was 20 miles an hour.
In a depth of 60 to 70 fathoms the velocity was 17 miles an hour.
In a depth of 34 to 40 fathoms the velocity was 17½ miles an hour.

In a depth of 51 fathoms the waves produced by a steam vessel passing at the distance of about a mile, moved at the rate of only 4·3 feet in a second.

It thus appears that the waves produced by the wind on the surface of the deep sea do not follow the same law with the great wave of the fluid. In other words they are not primary but secondary waves, or waves of some inferior order. They do not move with the velocity due to half the depth of the fluid in which they are generated.

The following are the most important and accurate observations made on this subject.

Observations.—The observations were made by bringing the vessel nearly to rest in a direction at right angles to the ridge of the wave. The cork fenders of the vessel were then attached at equal distances to the log-line, and spaces of 200 feet were marked off upon it. The time was taken by a common chronometer; the observations made were upon the transits of the top of the wave under the floating buoys attached to the log-line.

1. 4th Oct. 1836, lat. 55° 38′ N., long. 4° 49′ W.
Off the Cambray Islands, 60 to 70 fathoms.
Space 200 feet, time 7 sec. to 9 sec. = 25 feet per sec.
= 17 miles an hour.

2. 4th Oct., 1836, lat. 55° 32′ N., long 4° 52′ W.
Off the Isle of Arran, 50 to 60 fathoms.
Space 200 feet, time 10 sec. = 20· feet per sec. = 13·5 miles an hour.

3. 5th Oct. 1836, lat. 55° 29′ N., long. 4° 54′ W.
Of Pladda Lights, 20 to 16 fathoms.
Space 200 feet, time 11 sec. to 12 sec. = 17·3 feet per sec. = $11\frac{1}{2}$ miles per hour.

4. 12th Oct. 1836, lat. 54° 5′ N., long. 5° 31′ W.
Off Ardglass Light, in 34 to 40 fathoms.

$$\text{Space} = 345 \text{ feet} \begin{cases} \text{Time.} \\ 9{\cdot}3 \text{ sec.} \\ 10{\cdot}0 \\ 9{\cdot}3 \\ 8{\cdot}6 \\ 10{\cdot}0 \end{cases} = 35 \text{ feet} - 9 = 17\tfrac{1}{2} \text{ miles.}$$

5. 12th Oct. 1836, lat. 54° 1′ N., long. 5° 37′ W.
in 53 fathoms.

$$\text{Space} = 345 \text{ feet} \begin{Bmatrix} 9{\cdot}3 \text{ sec.} \\ 8{\cdot}6 \\ 8{\cdot}6 \end{Bmatrix} = 39 \text{ feet} - 9 = 20 \text{ miles per hour.}$$

6. 12th Oct. 1836, lat. 53° 58′ N., long. 5° 39′ W.
in 46 to 44 fathoms.
Space = 345 feet, time = 9·3 sec. = 37 feet —9 = 19 miles.

The observations (4-6) were made against a very strong breeze and very high waves, about 8 or 9 feet high, and the vessel was going in the opposite direction at about the rate of six miles an hour.

7. In 51 fathoms water the City of Glasgow steam packet passed; her waves were about 20 inches high, about 12 feet apart, and passed over a space = 150 feet in 35 sec. = 4·3 feet per sec.

It became of importance to determine whether the waves of the sea produce an agitation which extends to the deep parts of the water. It was found that even in moderate depths they do not. Thus in a depth of 12 feet—short quick waves, 9 inches high and 4 or 5 feet long, do not sensibly affect the water at the bottom, while waves thirty or forty feet long, oscillating at intervals of 6 or 8 seconds, produce a sensible effect, although much less than at a point nearer the surface. The circumstances of these partial oscillations opens up a field of future research. The observations made on this subject were obtained by plunging a glass tube to a considerable depth, so that the column of water contained in it should only be affected by the forces acting upon the particles of the fluid at the depth of its orifice below the surface. In this way it was ascertained that neither in velocity of the wave-surface, nor in the motion of transference of the particles, do the waves of the sea resemble the great primary wave of translation of the previous experiments.

It is difficult to ascertain with precision the form of the waves of the sea; they appear to belong to the family of the cycloid,

The summit of the wave is round and flat so long as its height bears only a small ratio to its length in the direction of its motion; but as the height increases the summit of the wave becomes more and more acuminated, and the limit to which the height of a wave approaches, but which it never appears to exceed, is nearly a third part of its length. If the wave belong to the cycloidal family, and if its length being constant the height vary with the generating radius, the rolling circle continuing the same, we shall have a series of lines accurately representing the form of the waves. See Plate II. fig. 1. Now it is manifest that when the describing radius of the wave becomes greater than the radius of the rolling circle, the curve ceases to have a form of possible equilibrium, and that portion which falls down from the top of the wave constitutes the white crest which we observe on the summits of the largest waves, when they are said to break.

There is generally much confusion in the appearance of an agitated sea. The waves do not appear regular in their forms, their intervals, or their velocities. Sometimes a wave seems to stand still or even to retrograde, and frequently after the eye has traced a wave for a considerable time it suddenly disappears altogether. Close attention will however discover some method in this irregularity.

The surface of the sea is seldom covered with only one series of successive waves. Every breeze that ruffles the surface of the sea generates a series of waves that move in the direction of the motion of the wind. These waves do not subside with the breeze which raised them, but continue their oscillations until the adhesion of the water or the resistance of the shore has diffused the elevated fluid uniformly over the surface. In the mean time a second breeze springs up in another direction, and new waves rise to its pressure and follow its direction; they mingle with those of the former wind without becoming mixed with them. Two distinct series of waves are now coexistent, and give rise to more complex phenomena. A third gale arises, and a new class of waves intersect and overlap the two former, while the long low swell—the residue and telegraph of some distant storm—rolls across the whole, and to the untutored eye leaves nothing to be looked on but a chaos of tumultuous, troubled waters. The seeming chaos is however to be analyzed by patient attention: by ascending the mast of the ship, or standing on an elevated rock on the shore, much of this apparent confusion may be dispelled; and by attention to the phenomena of coexistent oscillations every thing may be understood.

When a breeze has been blowing for some time in one direction, and the wind has shifted round into the opposite one and blown with nearly equal force, the two sets of waves may

be distinctly seen moving in opposite directions; if they be of nearly equal dimensions a very singular appearance results. When the crests coincide, the ordinates of the compound wave surface become the same ordinates of the elementary waves, and their difference when the crest of the one is in the cavity of the other; so that the sea is alternately in the forms represented in *c* and *d*, fig. 2, Plate II.

When these two systems of waves are compounded with a third system arising from some other breeze, or by a third system resulting from the reflection of a bold coast, the third series combines with the two former in the manner represented in fig. 3, with an appearance of still less regularity, and so on for any number of parallel systems.

It is manifest that if these parallel systems be compounded with transverse systems, making any angle with the first, we shall have a compound system of surfaces of double curvature so complex in its structure as to represent the phenomena of the most troubled sea. On all occasions where the sea was observed, there were found two or more such systems of coexistent waves.

The phenomena of the waves at the surface of the sea appear to coincide very well with the hypothesis, that when a wave agitates the fluid only to a small depth it may be considered as formed in a shallow canal of that depth; for it may be observed that a short wave of a given height is always more pointed than a longer wave of the same height, and also that whenever a wave reaches the limit of the cycloidal form it breaks.

Whenever the height of a wave exceeds the limit of the cycloidal form due to its depth, the wave, after having become cusped or pointed, passes into the nodated form of unstable equilibrium and is broken. See figs. 4 and 5.

Whenever a wave of a higher order coincides with the ridge of one of an inferior order, its curvature at the crest will be a maximum, and it may break, although it would not have broken on any other part of the wave. See figs. 4 and 5, Pl. II. From this cause a large wave frequently exhibits the appearance of a breaking wave, although its own figure has not approached the limits of equilibrium; but in that case it is not the large wave which is breaking, but the smaller one on its summit, whose curvature is then increased by the amount of the curvature of the greater wave at the crest.

Waves break on the shore when they reach the point where the depth of the fluid becomes nearly equal to the height of the wave above the fluid. When at a distance from the shore they may be observed long and low, see fig. 6; as they approach the

shallow part of the shore they gradually assume the greater curvature due to the increased ratio of height to depth ; the form at last becomes cusped and perfectly cycloidal, the equilibrium of the summit ceases, and the particles of water on the extreme ridge of the wave, abandoned to the force of gravity, and aggregated in spherical drops by this cohesion, present to the eye the white foaming crest by which breakers are distinguished. Waves of great height are thus broken on the beach at a greater distance from the shore than such as are smaller.

The depth of water may be judged of by the form and height of the waves. See fig. 7, Plate II. Where a wave of a given height can exist, suppose a wave of five feet, the water must have a depth below the surface of at least five feet, and wherever in a calm day waves are broken, the depth of the water is equal to their height above its surface.

It must be observed that the existence of a strong *wind* will often destroy the equilibrium of the ridge of a wave, independent of depth or of the equilibrium of its proper form. When the curvature of the ridge of the wave becomes considerable, and it approaches the cusped form, the direct incidence of the wind upon the surface of the ridge will derange the equilibrium of the thin and slender column presented by the top of it before it reaches the limits of undisturbed equilibrium. Hence the phenomenon well known to sailors, that a very strong wind will blow the sea down, in other words, that it will blow off the ridges of the highest waves, and keep them from attaining the height they afterwards reach when the gale has subsided. The highest seas are thus generated by the continuance of a strong gale in one direction rather than by the sudden and short impulse of a hurricane; for in the former case the wind only breaks the summits of the smaller waves as they rise to the top of the larger ones, so as to add the mass of the smaller to the crest of the larger waves, without injuring the equilibrium of the latter; these continual additions increase the magnitude of these great waves, while the force of the gale is not sufficiently great to derange their equilibrium. The waves in these circumstances go on increasing in magnitude.

The phenomena of waves breaking on the shore were observed principally on a very fine smooth beach of sand, having a slope towards the sea of 1· in 50· ; so perfectly plane and level was it at the time when the observations were made, that a single wave a mile in breadth might be observed advancing to the shore, so perfectly parallel to the edge of the water that the whole wave rose, became cusped, and broke at the same instant ; a line of graduated rods was fixed in the water at different depths from

6 inches to 6 feet in length, and it was observed that every wave broke exactly when its height above the antecedent hollow was equal to the depth of the water. At another time when the direction of the waves was oblique to the edge of the water, the breaking crest moved along from one end of the shore towards the other, uniformly and gradually as the wave advanced to the point of breaking depth, resembling the *feu de joie* of a file of soldiers.

When a wave that has been breaking on a shallow part of the water comes suddenly into deeper water, the form ceases to be crested, see Plate II.; and the wave subsides into the figure due to the depth.

The phenomena of waves breaking on the shore were accurately obtained in the experiments No. 107—132, page 492. Plate II. figs. 6 and 7.

Third Series of Observations.

On the Tide Wave of the River Dee in Cheshire.—The object of this series of observations was the comparison of the *tidal wave* moving in a given channel with the great *primary wave of translation* previously examined by Mr. Russell.

To this object the river Dee is peculiarly suitable. Plate VI. fig. 1. gives a plan of that river at low water. The upper portion of the channel of the river is artificial. The waters of the river were turned into a new course about the middle of the last century. Of this course about $5\frac{1}{4}$ miles forms a perfectly straight canal, along which a large and rapid tidal wave is transferred with great velocity. The two points A and B on the plan were selected as stations of observation. The distance between A and B was carefully measured; transverse sections of the river were made, and soundings were taken throughout the whole length of the channel.

The distance between A and B	= 5·275	miles.
The mean depth of the channel at low water	= 3·0	feet.
The bed of the river has a slope nearly .	= 3·8	feet.

The opposite sides of the river are parallel embankments about 500 feet apart at high water mark, but nearly half that breadth is occupied by groins, as shown in the sections of the river, figs. 2, 3, and 4, Plate VII., and the intervals between them are filled up with high banks of sand.

The tides selected to be observed were those which differed most in magnitude, and which were least affected by disturbing influences. They were made when the weather was settled, when there was no sensible wind, and when the river was as nearly as possible in its natural state. One entire tide wave was obtained on the 7th of September, and two others on the 9th

and 13th of that month. In the latter two cases the river was a few inches fuller than in the former, as will appear by inspecting the table of observations which follows.

From these observations it may be useful to make the following extracts.

First wave of flood tide, 7th Sept. reached		
Station A at	6^h	50^m
Station B at	7	50·
Time of describing 5·275 miles	1	0·
First wave of flood tide, 9 Sept. reached		
Station A at	8	5·
Station B at	8	50·
Time of describing 5·275 miles	0	45·
First wave of flood tide, 13th Sept. reached		
Station A at	10	15·
Station B at	11	0·
Time of describing 5·275 miles	0	45·
The wave of high water of 7th Sept. reached		
Station A at	9	21·
Station B at	9	50·75
Time of describing 5·275 miles	0	29·75
The wave of high water of 9th Sept. reached		
Station A at	10	35·
Station B at	10	54·5
Time of describing 5·275 miles	0	19·5
The wave of high water of 13th Sept. reached		
Station A at	12	35·
Station B at	12	53·5
Time of describing 5·275 miles	0	18·5

The following table contains the corresponding velocities of the waves.

WAVE.	Velocity in miles.	Height of Wave at A.	Height of Wave at B.	Mean Depth.	Height due to the Velocity.
I.	5·2	0·ft.8·in.	0·ft.6·in.	3·ft.7·0in.	2·0ft.
II.	7·0	1· 6·	0· 7·	4· 10·5	3·5
III.	7·0	2· 8·	1· 1·	5· 0·5	3·5
IV.	10·5	9· 2·1	6· 4·	10· 9·0	7·0
V.	16·2	13· 5·7	10· 6·	15· 11·8	16·0
VI.	17·1	15· 8·	13· 0·	17· 4·0	17·0

In order to make these observations the foundation of any conclusions, it will be necessary to observe that it is scarcely possible to determine whether the wave which brings flood tide to the lower station be the same with that which afterwards brings flood tide to the higher station; on the other hand it seems more likely that the wave which passed the lower station was diffused over the intermediate space in the channel, and was overtaken by a subsequent part of the tide, which had not reached the lower station till a considerable time after the first wave had passed it. This is not a conjecture, but has frequently been observed in similar cases where the first wave being become diffused in the channel ceased to pass onwards and was overtaken by a subsequent wave. The result obtained in the case of waves I., II., and III. of flood tide is consistent with this view, and shows that in these cases the progress of flood tide is slower than the velocity due by gravity to the wave of the fluid. It is also consistent with the experiments of the previous part of this paper, that a breaking wave or bore, as this was, has a slower velocity than one which does not break.

Waves IV., V., and VI., the waves of high water, have almost exactly the velocities of great waves of translation of the fluid. It will be seen at once by examining the transverse sections of the river, that wave IV. must suffer great retardation from the circumstance that its progress is continually intercepted by the groins to which it is almost exactly equal in height, while waves V. and VI. rise above them and accordingly approximate more closely to the velocity due to the depth. The form of these waves and their antecedent bores are given in Plate VI. figs. 1 and 2. and the observations from which they are deduced are given in the following table.

Tide Wave of the 7th Sept., River Dee, 1836.

Station A, Jarvis Obs., Chron. No. 4 stand. H. W. $9^h\ 21^m$ = 9ft. 2·1in.				Station B, Jones Obs., Chronom. No. 2, cor. = + $0·75^m$. H. W. $9^h 50^m·75$ = 6ft. 4in.			
Flood.		Ebb.		Flood.		Ebb.	
h. m.	ft. in.	h. m.	ft. in.	h. m.	ft. in.	h. m.	ft. in.
9 20	9 2·1	9 20	9 2·1	9 50	6 4·	9 50	6 4·
15	9 1·7	Not	observed.	45	6 3·7	55	6 3·7
10	9 1·7			40	6 3·0	10 0	6 2·5
5	9 1·7			35	6 2·0	5	6 2·0
0	9 1·5			30	6 0·7	10	6 0·5
3 55	9 1·5			25	5 11·	15	5 11·0
50	9 0·5			20	5 8·7	20	5 9·7
45	8 10·5			15	5 6·3	25	5 8·0
40	8 ..			10	5 3·7	30	5 6·7
35	8 6·5			5	5 0·7	35	5 5·0
30	8 4·			0	4 10·0	40	5 3·0
25	8 1·			8 55	4 7·0	45	5 1·5
20	7 10·5			50	4 4·	50	4 11·7
15	7 7·			45	4 0·7	55	4 10·5
10	7 4·			40	3 10·	11 0	4 9·0
5	7 1·			35	3 6·5	5	4 7·5
0	6 8·3			30	3 3·5	10	4 6·0
7 55	6 6·5			25	3 0·3	15	4 4·
50	6 5·0			20	2 9·2	20	4 3·
45	5 11·5			15	2 6·5	25	4 1·5
40	5 8·5			10	2 3·3	30	4 0·
35	5 6·0			5	2 0·	35	3 10·5
30	5 1·0			0	1 9·	40	3 9·
25	4 9·			7 55	1 6·	45	3 7·5
20	4 4·			50	1 2·	50	3 6·
15	4 0·			45	0 8·3	55	3 4·7
10	3 7·			40	0 7·	12 0	3 3·0
5	3 1·			35	0 5·	5	3 3·1
0	2 8·			30	0 4·	10	3 0·5
6 55	2 1·			25	0 3·7	15	2 11·2
50	1 9·			20	0 3·5	20	2 10·5
45	1 1·			15	0 3·	25	2 9·3
40	0 11·			10	0 2·7	30	2 8·0
35	0 8·			5	0 2·5	35	2 7·0
30	0 6·			0	0 2·0	40	2 6·0
25	0 ..			6 55		45	2 5·0
20	0 2·			50		50	2 4·2

Tide Wave of the 9th Sept., River Dee, 1836.

Station A, Jarvis Obs., Chron. No. 4 stand. H. W. $10^h\ 35^m$ = 13 ft. 5·75 in.				Station B, Jones Obs., Chron. No. 2 cor. = − $0{\cdot}5^m$. H. W. $10^h\ 54{\cdot}^m5$ = 10 ft. 6 in.			
Flood.		Ebb.		Flood.		Ebb.	
h. m.	ft. in.	h. m.	ft. in.	h. m.	ft. in.	h. m.	ft. in.
10 35	13 5·7	10 35	13 5·7	10 55	10 6·	10 55	10 6·
30	13 5·5	40	13 5·7	50	10 5·5	11 0	10 5·5
25	13 4·5	45	13 5·	45	10 4·	5	10 5·
20	13 3·	50	13 3·	40	10 2·5	10	10 3·5
15	13 1·	55	13 1·5	35	10 0·5	15	10 2·0
10	12 1·1	11 0	12 11·	30	9 10·	20	10 0·
5	12 8·5	5	12 9·	25	9 7·5	25	9 9·5
0	12 6·5	10	12 7·5	20	9 5·	30	9 7·0
9 55	12 4·0	15	12 5·0	15	8 11·?	35	9 3·5
50	12 0·5	20	12 2·5	10	8 9·5	40	9 1·0
45	11 10·0	25	12 0·	5	8 5·	45	8 9·5
40	11 7·5	30	11 9·	0	8 1·5	50	8 7·0
35	11 4·	35	11 6·	9 55	7 8·5	55	8 3·5
30	11 1·5	40	11 3·	50	7 3·	12 0	8 0·0
25	10 11·	45	11 0·	45	6 10·5	5	7 9·0
20	10 7·5	50	10 9·	40	6 6·	10	7 6·5
15	10 4·	55	10 5·	35	6 1·	15	7 3·5
10	9 11·	12 0	10 2·	30	5 8·	20	7 2·0
5	9 6·	5	9 11·	25	5 3·	25	6 11·
0	9 1·	10	9 8·	20	4 10·	30	6 8·
8 55	8 8·	15	9 4·	15	4 4·5	35	6 6·
50	8 2·	20	9 1·	10	3 10·5	40	6 3·
45	7 8·	25	8 10·	5	3 5·	45	6 1·
40	7 1·5	30	8 7·5	0	2 10·	50	5 10·5
35	6 7·5	35	8 4·	8 55	2 3·	55	5 8·5
30	6 0·	40	8 1·	50	1 5·	1 0	5 5·0
25	5 5·	45	7 11·	45	0 10·	5	5 4·
20	4 9·	50	7 8·	40	0 4·	10	5 1·
15	4 0·	55	7 5.	35	0 4·	15	4 11·5
10	3 2·	13 0	7 2·	30	0 4·	20	4 $9\frac{1}{4}$·
5	2 4·	5	6 11·			25	4 7·
0	0 10·	10	6 6·7			30	4 5·5
		15	6 5·			35	4 3·
		20	6 2·5			40	4 1·5
		25	5 11·5			45	3 11·5
		30	5 9·0			50	3 10·
		35	5 5·2			55	3 8·

The observations under the words flood and ebb are uncorrected for the error of the chronometer: the correction is given at the head of each column.

The time and magnitude of high water are correctly given at the head of each column.

The time and magnitude of the same tides as given in the almanack for Liverpool are

Sept. 7,	8^h	57^m	10 ft.	10 in.
Sept. 9,	10	26	13	7
Sept. 13,	0	37	18	0

Tide Wave of the 13th Sept., River Dee, 1836.

Station A, Jarvis Obs., Chron. No. 4 stand. H. W. $12^h\ 35^m$ = 15 ft. 8 in.								Station B, Jones Obs., Chron. No. 2 cor. = $-1^{\cdot m}5$. H. W. $12^h\ 53^{\cdot m}5$ = 13 ft. 0· in.							
Flood.				Ebb.				Flood.				Ebb.			
h.	m.	ft.	in.	h.	m.	ft.	in.	h.	m.	ft.	in.	h.	m.	ft.	in.
12	35	15	8·	12	35	15	8·	12	55	13	0·	12	55	13	0·
	30	15	7·5		40	15	7·		50	12	11·7	1	0	12	11·7
	25	15	6·5		45	15	6·		45	12	10·7		5	12	9·5
	20	15	5·		50	15	5·		40	12	10·0		10	12	6·5
	15	15	4·		55	15	4·		35	12	8·0		15	12	3·7
	10	15	3·	1	0	15	3·		30	12	5·0		20	12	0·7
	5	15	1·5		5	15	0·		25	12	0·		25	11	10·
	0	15	0·		10	14	9·		20	11	7·		30	11	7·
11	55	14	9·		15	14	5·5		15	11	2·		35	11	4·
	50	14	5·5		20	14	2·7		10	10	7·5		40	11	1·
	45	14	2·		25	13	11·		5	9	11·5		45	10	10·5
	40	13	10·		30	13	9·		0	9	4·0		50	10	7·0
	35	13	6·		35	13	5·	11	55	8	9·0		55	10	3·0
	30	13	2·		40	13	2·		50	8	1·0	2	0	10	0·
	25	12	9·		45	12	10·		45	7	7·0		5	9	8·
	20	12	5·		50	12	7·		40	7	3·5		10	9	4·
	15	12	3·		55	12	3·		35	6	9·		15	9	0·
	10	11	7·	2	0	12	0·		30	5	11·5		20	8	9·
	5	10	10·5		5	11	7·5		25	5	4·0		25	8	6·
	0	10	4·		10	11	4·		20	4	8·0		30	8	3·
10	55	9	6·		15	11	0·		15	3	11·0		35	7	11·5
	50	8	10·		20	10	6·5		10	3	0·0		40	7	8·
	45	8	0·		25	10	3·		5	2	3·0		45	7	5·
	40	7	3·		30	10	0·		0	1	3·0		50	7	3·
	35	6	5·5		35	9	6·	10	55	0	2·		55	7	0·
	30	5	9·		40	9	1·5					3	0	6	9·
	25	4	10·		45	8	11·						5	6	5·
	20	3	11·		50	8	6·						10	6	3·
	15	2	10·		55	8	2·						15	6	1·
	10	0	..	3	0	7	10·						20	5	9·
	5	..	..		5	7	6·5						25	5	7·
	0	..	..		10	7	2·						30	5	4·
					15	6	10·7						35	5	0·
					20	6	7·3						40	4	9·
					25	6	3·7						45	4	6·
					30	6	0·5						50	4	3·7
					35	5	9·						55	4	1·
					40	5	5·5						60	3	10·5

It was observed that the flood tide of the 13th was attended in passing the lower station, A, with a very considerable breaking bore or surge on the sides.

Both of the tide gauges were placed in deep water at some distance removed from the banks of the river.

Fourth Series of Observations.

On the Tide Wave of the River and Frith of Clyde in Scotland.—The observations on the river Dee having been necessarily very limited in number, and in the means as well as objects of inquiry, suggested the nature and indicated the necessity of a more extensive series of observations of the tide wave in its progress along some limited channel whose dimensions might be determined with the requisite precision. The river and frith of Clyde on the west coast of Scotland were at once suggested to the Committee, as in every way suitable to the objects of their inquiry. That river is, like the Dee, contained in a channel, which is a work of art rather than of nature, having been rendered one of the finest rivers in Britain by the perseverance, enterprise, and wealth of the citizens of the important manufacturing and commercial city, whose merchandise it transports from all quarters of the world. Your Committee made application, with the assistance of Sir Thomas Brisbane, the President of the Royal Society of Edinburgh, and one of the former presidents of the British Association, to the board of Commissioners or Trustees of the navigation of the Clyde, and were fortunate in obtaining their cordial and effectual co-operation in conducting all the observations and obtaining all the information they required. The willing assistance of Mr. Logan the engineer of the river, was given in conducting the observations; at his request simultaneous observations were made at several other ports in the vicinity; Captain Denham, R.N., of Liverpool, was good enough to order similar observations at that port; Professor Nicol kindly placed the instruments in the college observatory at their disposal, for regulating the time-keepers of the observers, and nothing was omitted that could give the observations value and general interest. Moreover, it was fortunate that the board of Trustees had just obtained very accurate surveys of the river with transverse sections, at distances of each quarter of a mile; and they further ordered that the stations of observation should be connected by a system of levelling. These were all placed at the disposal of the Committee by the Trustees and their engineer, who were of opinion that observations of that nature were of equal value to the practical navigation and improvement of their river, as to the theoretical speculations of the British Association.

Throughout the greater part of 18 miles, the distance between Glasgow and Port-Glasgow, the river Clyde is little more than an inland tidal canal, excavated and embanked by artificial means; it then expands into a frith of considerable breadth,

extending about 25 miles down to the outer Cumbray Island, where it terminates. The whole of this space was embraced by the observations.

Plate VII. contains a plan of the river Clyde; the stations at which tide gauges were erected and observers placed are marked in the plan. Nine different stations were occupied; the first of these was at the harbour at Glasgow, immediately below which, the river is for about 5 miles of nearly uniform width and depth, and in this division were three stations, No. I., II., and III. The next division of the river is wide, irregular, and of variable depth, comprehending stations III., IV., and V. The third division of the river is deep and broad from station V. to station VII. The river then opens out into a wide and deep frith, and at a distance of about 5 miles further down, on opposite sides of the frith, were placed stations VIII. and X. Station IX. was at the light-house on the outer Cumbray Island, which stands at the mouth of the frith. A great variety of channel was thus included in the observations.

The observations were made with a tide-gauge, constructed for the purpose of preventing the oscillations of the waves of the surface; a glass tube traversed the scale; the tube open above terminated below in a stop-cock, by which the aperture was regulated, and which communicated with a long narrow pipe descending into deep water; the indications of this gauge were free from inconvenient oscillation, even in a rough sea, to which it was exposed. The scale of the gauge was so constructed as to be read with ease at a considerable distance. This gauge is recommended as one that can be used with ease and perfect accuracy by a telescope from a great distance, and which might therefore afford the means of making observations in situations where otherwise it would be impracticable. The indications of the gauge were written down every five minutes during the entire progress of one tide wave each day, and of two successive tide waves on the evening of each Friday. The following table contains the observations of heights, all referred to the same level, as accurately determined by Mr. Kyle for the first seven stations, and as interpolated for eight and nine.

TABLE of the Observations on the Height of the Tides in the River and Frith of Clyde during April and May, 1837.

STRENGTH & DIRECTION OF WIND:		April 20. Gentle, S.W.	April 21. Gentle, S.E. & E.	April 22. Fresh, E. & S.E.	April 24. Gentle, E. & W.	April 25. Moderate, S. & S.E.	April 26. Strong, W.&S.W.	April 27. Gentle, W.&S.W.	April 28. Gentle, W.&S.W.	April 29. Fresh, E. & S.E.	May 1. Strong, W. & S.W.
		Ft In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
STATION I. BROOMIELAW.—To find the Height on the Gauge, subtract 3·44 Feet.	High W. M.	...	11 10·25	11 4·2	11 9·2	12 1·2	11 11·2	10 11·2	10 2·3	9 9·2	13 0·2
	Low W. M.	...	...	...	4 0·3	4 6·3	4 7·0	4 3·7	3 10·5	4 2·3	...
	Rise and Fall,	...	...	...	7 8·9	7 6·9	7 4·2	6 7·5	6 3·8	5 6·9	...
STATION II. CRAWFORD'S QUAY.—To find the Height on the Gauge, subtract 3·01 Feet.	High W. M.	11 6	11 9·5	11 3·2	11 8·0	12 0·2	11 10·7	10 11·2	10 1·7	9 10·2	12 10·7
	Low W. M.	3 9	3 9·2	3 8·7	3 11·2	4 2·2	4 4·7	4 1·0	3 8·2	...	6 4·7
	Rise and Fall,	7 9	7 11·3	7 6·5	7 8·8	7 10·0	7 6·0	6 10·2	6 4·5	...	6 6·0
STATION III. CLYDE BANK.—To find the Height on the Gauge, subtract 3·01 Feet.	High W. M.	...	11 6·1	11 1·7	11 5·1	11 9·9	11 7·6	10 8·1	9 11·6	9 9·1	12 7·1
	Low W. M.	...	3 7·6	3 9·1	3 10·1	4 1·1	4 3·1	3 11·1	3 6·3	3 7·1	6 1·2
	Rise and Fall,	...	7 10·5	7 4·6	7 7·0	7 8·8	7 4·5	6 9·0	6 5·3	6 2·0	6 6·9
STATION IV. RASHILEE PIER.—To find the Height on the Gauge, subtract 3·3 Feet.	High W. M.	...	...	...	...	...	11 6·0	10 7·2	9 10·5	9 10·0	...
	Low W. M.	...	...	...	...	...	4 0·2	3 8·7	3 4·2	3 11·7	...
	Rise and Fall,	...	...	...	...	...	7 5·8	6 0·5	6 6·3	5 11·3	...
STATION V. BOWLING BAY.—To find the Height on the Gauge, subtract 2·6 Feet.	High W. M.	...	...	...	11 6·3	11 10·3	11 4·8	10 6·3	9 8·3	9 8·3	12 4·5
	Low W. M.	...	...	...	...	2 11·3	3 4·3	3 0·3	2 8·8	2 8·3	4 3·3
	Rise and Fall,	...	...	...	...	9 11·0	8 0·5	7 6·0	6 11·7	7 0·0	6 1·2
STATION VI. GARMOYLE.—To find the Height on the Gauge, add 7 Inches.	High W. M.	...	...	...	11 3·7	11 8·5	11 1·0	10 2·0	9 5·5	9 8·7	11 8·0
	Low W. M.	...	...	...	...	1 0·0	1 9·0	1 0·2	1 8·2	1 7·0	1 10·0
	Rise and Fall,	...	...	...	...	10 8·5	9 4·0	9 1·8	7 9·3	8 1·7	9 10·0
STATION VII. PORT GLASGOW.—To find the Height on the Gauge, subtract 1·03 Feet.	High W. M.	...	11 3·8	10 9·4	11 0·8	11 6·9	10 10·6	10 1·1	9 4·1	9 5·8	11 3·4
	Low W. M.	...	...	...	...	0 10·2	...	1 11·8	1 10·1	1 9·8	1 6·3
	Rise and Fall,	...	...	...	...	10 8·7	...	8 1·3	7 5·0	7 8·0	9 9·1
STATION VIII. CLOCH LIGHT.—To find the Height on the Gauge, subtract 6 inches.	High W. M.	...	...	...	10 9·5	11 3·5	10 7·0	9 9·5	9 1·5	9 4·5	...
	Low W. M.	...	...	...	...	...	1 9·0	1 10·	1 9·7	1 10·5	1 3·2
	Rise and Fall.	...	...	...	...	...	8 10·0	7 11·5	7 3·8	7 6·0	...
STATION IX. CUMBRAY LIGHT.—To find the Height on the Gauge, subtract 6 inches.	High W. M.	...	...	...	...	...	...	...	...	...	...
	Low W. M.	...	...	...	...	...	...	...	...	...	...
	Rise and Fall,	...	...	...	...	...	...	...	...	...	...

TABLE of Observations continued.

STRENGTH & DIRECTION OF WIND		May 2. Strong, W.	May 3. Gentle, E.	May 4. Strong, N.W.	May 5. Moderate, E. & W.	May 6. Gentle, E. & W.	May 8. Moderate, E.	May 9. Smart, N.E.	May 10. Gentle, S.	May 11. Gentle, E. by S.	May 12. Gentle, S.	May 13. Gentle, S.
		Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
STATION I. BROOMIELAW.—To find the Height on the Gauge, subtract 3·44 Feet.	High W. M.	12 2·7	11 10·7	12 5·5	11 9·7	11 4·5	10 11·2	10 4·2	10 2·2	9 6·5	9 6·0	...
	Low W. M.	5 8·7	4 2·3	4 10·0	4 1·7	3 7·0	3 10·2	3 8·8	3 8·8	3 5·8	3 10·2	...
	Rise and Fall,	6 6·0	7 8·4	7 7·5	7 8·0	7 9·5	7 1·0	6 7·4	6 5·4	6 0·7	5 7·8	...
STATION II. CRAWFORD'S QUAY.—To find the Height on the Gauge, subtract 3·01 Feet.	High W. M.	12 1·7	11 9·2	12 4·2	11 8·5	11 3·2	...	...	...	...	...	...
	Low W. M.	5 4·5	4 2·2	4 8·2	4 0·2	3 7·7	...	...	...	...	...	...
	Rise and Fall,	6 9·2	7 7·0	7 8·0	7 8·3	7 5·5	...	...	...	...	...	...
STATION III. CLYDE BANK.—To find the Height on the Gauge, subtract 3·01 Ft.	High W. M.	11 11·3	11 7·3	12 0·1	11 5·3	11 0·9	...	...	...	...	...	...
	Low W. M.	5 0·1	3 11·1	4 3·1	3 11·6	3 6·1	...	...	...	...	...	...
	Rise and Fall,	6 11·2	7 8·2	7 9·0	7 5·7	7 6·8	...	...	...	...	...	...
STATION IV. RASHILEE PIER.—To find the Height on the Gauge, subtract 3·3 Feet.	High W. M.	...	...	...	...	...	...	...	...	...	...	...
	Low W. M.	...	...	...	...	...	...	...	...	...	...	...
	Rise and Fall,	...	...	...	...	...	...	...	...	...	...	...
STATION V. BOWLING-BAY.—To find the Height on the Gauge, subtract 2·6 Feet.	High W. M.	11 8·3	11 6·6	11 10·3	11 5·6	11 2·3	...	...	...	...	...	...
	Low W. M.	4 1·8	3 1·8	3 2·3	3 0·3	2 9·8	...	...	...	...	...	...
	Rise and Fall,	7 6·5	8 4·8	8 8·0	8 5·3	8 4·5	...	...	...	...	...	...
STATION VI. GARMOYLE.—To find the Height on the Gauge, add 7 Inches.	High W. M.	11 3·2	11 3·2	11 5·0	11 2·0	10 11·	...	...	..	...	...	...
	Low W. M.	2 7·0	1 7·0	1 3·0	1 1·5	0 10·	...	...	...	...	...	...
	Rise and Fall,	8 8·2	9 8·2	10 2·0	10 0·5	10 1·	...	...	...	...	...	...
STATION VII. PORT GLASGOW.—To find the Height on the Gauge, subtract 1·03 Feet.	High W. M.	11 1·3	11 1·3	11 3·1	10 11·8	10 9·6	...	...	...	...	...	...
	Low W. M.	2 4·3	1 7·3	0 10·9	0 10·8	0 5·8	...	...	...	...	...	...
	Rise and Fall,	8 9·0	9 6·0	10 4·2	10 1·0	10 3·8	...	...	...	...	...	...
STATION VIII. CLOCH LIGHT.—To find the Height on the Gauge, subtract 6 In.	High W. M.	10 9·2	10 10·0	10 10·5	10 7·7	10 6·0	9 11·7	9 4·2	9 1·2	8 8·0	8 5·7	9 0·0
	Low W. M.	2 5·5	1 6·5	1 0·0	0 8·2	0 5·0	1 1·2	1 2·5	1 8·7	2 2·0	3 2·2	2 4·0
	Rise and Fall,	8 3·7	9 3·5	9 10·5	9 8·5	10 1·0	8 10·5	8 1·7	7 4·5	6 6·0	5 3·5	6 8·0
STATION IX. CUMBRAY LIGHT.—To find the Height on the Gauge, subtract 6 in.	High W. M.	...	10 0·2	10 1·0	9 9·5	9 8·2	9 2·5	8 7·2	8 4·5	7 11·7	7 9·7	...
	Low W. M.	...	1 4·7	0 11·0	0 8·0	0 6·0	0 11·2	1 0·7	1 6·5	1 10·7	2 10·2	...
	Rise and Fall,	...	8 7·5	9 2·0	9 1·5	9 2·2	8 3·3	7 6·5	6 10·0	6 1·0	4 11·5	...

From these observations it appears that the summit of the tide wave increases in height as it ascends the river. From station VII. to station VI. this increase amounts to about 2 inches; at station V. it amounts to 5·2 inches; at III. it has become 6·1 inches; and at Glasgow 10·1 inches is the difference between the level of the wave of high water above that at Port Glasgow, 18·5 miles below. This difference varies slightly with the state of the tides, and with the condition of the current of fresh water in the river. At low water the surface of the river is higher at Glasgow than at Port Glasgow by 33 inches; at station III. this difference is 27 inches, at IV. about 25 inches, and at V. about 12 inches.

	Difference of level at H. W.	Difference of level at L. W.
Station I.	10·1 inches.	33 inches.
Station II.	9·1 inches.	31 inches.
Station III.	7·0 inches.	27 inches.
Station IV.	6·1 inches.	25 inches.
Station V.	5·2 inches.	12 inches.
Station VI.	2·2 inches.	5 inches.
Station VII.	0·0 inches.	0 inches.

The comparison of these numbers with the channel of the rivers in Plate VIII. will be interesting, as showing the influence of the form of the channel upon the height of the tide wave and the current of the river.

Plate V. is a diagram showing the height of the tide wave as it reached the successive stations in various states of the wind. The waves are transposed so as to have a common origin, at station VIII. The effect of westerly winds in increasing the height of the wave, and of easterly winds in depressing it, is manifest. The wave of the 24th of April is curious in this respect, that whereas the wind had been westerly, and changed, during the progress of the high water, to the east, so the wave which previously was higher, afterwards becomes lower than those adjacent to it; it therefore intersects them. The wind was in no case equivalent to what is considered a gale or storm.

Plate IV. represents the form of the tide wave as it passed the successive stations on the River and Frith of Clyde. A series of stars marks the centre of the wave, and has been placed there for the purpose of showing the *dislocation* of the wave, or the transposition of its higher parts forward, or the retardation of its lower parts by the shallowness of the water through which it has advanced. There is a remarkable reversion of this process in the wave of the Cumbray, Station IX.,

which is probably produced by the circumstance that it is the result of two waves (one behind the other). The corresponding wave at Liverpool is also given; it is also a compound of two waves, which coincide nearly in time.

From a laborious discussion of these observations, it appears that the wave of high water travels

From IX. to VIII.	in 6 min.	14 miles.	80 miles an hour.
From VIII. to VII.	in 9 min.	6 miles.	
From VII. to VI.	in 6 min.	3·75 miles.	20 miles an hour.
From VI. to V.	in 18 min.	4·25 miles.	
From V. to IV.	in 19 min.	2·5 miles.	8·1 miles an hour.
From IV. to III.	in 18 min.	2·5 miles.	
From III. to II.	in 15 min.	2·75 miles.	15 miles an hour.
From II. to I.	in 7 min.	2·75 miles.	

These results show that in the deep water being between 40 and 60 fathoms, or between 240 and 360 feet deep, the wave travels at the enormous rate of 30 miles an hour; that on reaching water from 20 to 30 feet deep, the velocity is diminished to 20 miles an hour; and from V. to II. where the river is wide, shelving, and shallow, the velocity of the tide wave is retarded to 8 miles an hour; while on ascending further up, where the banks nearly upright, and the contracted width give an increase of mean depth, the velocity has a corresponding increase to 15 miles an hour.

By examining the plans it will be apparent that we shall not err greatly if we assume the average depth of the river, from I. to III., at 15 feet. From III. to V. the river is wide and shallow, spreading over extensive banks, where there are not 2 feet of water, for which we may be allowed to take a third part of the greatest as a mean depth, or about 5 feet. In the division from V. to VII., both depth and breadth increase very rapidly to about 35 and 37; taking 25 feet as the mean depth, we have

Velocities of the Tide-wave as observed.	Mean depth.	Velocity due to depth.
80 miles an hour.	240—360 feet.	60—80 miles.
20 miles an hour.	25 feet.	19·3 miles.
8·1 miles an hour.	5 feet.	8·6 miles.
15 miles an hour.	15 feet.	14·9 miles.

The following are the results of the observations in regard to the time of high water:—

At Cloch Light,—High Water is 9 Min. earlier than at Port Glasgow.

Lazaretto-Point	5	do.	do.
Cumbray Light-house	15	do.	do.
Port-Patrick	31	do.	do.

At Cloch Light,—High Water is	51	Min. earlier than at	Port Glasgow.
Liverpool	51	do.	do.
Whitehaven	62	do.	do.
Newry	85	do.	do.
Donaghadee	127	do.	do.
Port-Rush	5 h. 35	do.	do.
At Garmoyle Light,—H. W. is	6	Min. later than at	Port Glasgow.
Bowling	24	do.	do.
Rashilee	43	do.	do.
Clyde Bank	61	do.	do.
Crawford's Quay	76	do.	do.
Broomielaw	83	do.	do.

Being 1 hour 23 minutes between Port Glasgow and the Broomielaw.

It is difficult to determine whether the wind produced a decided effect on the velocity of these tides. By a discussion which was attempted, it appeared that on all the days in which the easterly wind prevailed, compared with all the days on which the westerly wind prevailed, there was a difference of one minute more and of one minute less than the mean; the tide being accelerated by the coincident wind and retarded by the opposing one.

The continuation of this series of inquiries will be given in the next Report.

Description of the Tables containing the original Observations of the Waves in Artificial Channels made in 1837.

Each of the first ninety-three tables contains the history of a single wave, including the condition of the fluid previous to generation—the method of generation—the volume of the wave at the commencement of its path—the height of the wave at every transit—the interval between its transits—the space described, and the time occupied in describing it. The methods of observing and the observers' names are given, for the sake of authenticity, except in the first four experiments, which are not sufficiently perfect to form by themselves the grounds of any important conclusions.

The *approximate depth* of the fluid is given at the head of each table in the first line for convenience of reference.

The *corrected or true depth* of the fluid at the commencement of the observations is given immediately above the columns of observations, where it is given as "corrected statical depth =".

The "*observed statical level*" is the indication of the height of the fluid on the scale of the glass indices or gauges represented in Plate I., taken from an arbitrary line and affected by an index

error, from which the "corrected statical level" is derived by a correction obtained from observation.

The *modes of generating the fluid* were very numerous, but as the resulting phænomena of the waves were found to be independent of the mode of generation, a sufficient number only are given to establish the means of comparison. These extend from Wave I. to Wave XXV. Those waves "created by reservoir A" were formed by filling that portion of the channel at the end of the experimental channel of Plate I. with a given volume of water, which was added to the water in the channel by the sudden removal of the sluice S, and so formed the wave. The waves "generated by impulsion" of sluice were formed by placing the sluice at the back of reservoir A, and suddenly bringing it to the front of the reservoir, so as to communicate a horizontal impetus to the fluid forming the wave. The waves "generated by detached chamber B" were formed by placing the rectangular vessel B, Plate I., at the end of the reservoir and filling it with water to a given volume: by raising the sides of this vessel from the bottom of the reservoir, the column of water was allowed to descend by gravity and generate the wave.

Column A contains the number of feet described by the wave from the commencement of the observations.

Column B contains the interval of time given by two observers and two chronometers, α and β: these intervals of time correspond to the spaces in column A.

Column C contains the observations of height of the wave made in two sets of glass indices—index γ near the end B of the experimental channel, and index δ near the end D, Plate I.

Column D contains the heights of the waves at γ and δ, freed from error of scale.

Column E contains the sum of the corrected height of the wave and of the corrected depth of the fluid, taken from a mean of the observations.

2nd Aug., 1837. WAVE I. Depth 4 inches.

Created by Reservoir A. Volume of added fluid = 152·5 inches.
Transits observed directly at Index γ, without reflection.
Statical level observed at $\left\{ \begin{array}{l} \gamma = -\ 0{\cdot}05 \\ \delta = -\ 0{\cdot}01 \end{array} \right\}$ Corrected statical depth = 3·942 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
...	....	...	0·50	0·60	0·55	0·61	...	280·	81·5	...	0·20	0·17	0·25	0·18	4·17
0·	0·0	...	0·50	0·50	0·55	0·51	4·50	320·	84·0	...	0·15	0·17	0·20	0·18	4·15
40·	12·0	...	0·47	0·43	0·52	0·44	4·46	360·	105·0	...	0·10	0·15	0·15	0·16	4·12
80·	23·6	...	0·37	0·40	0·42	0·41	4·40	400·	117·0	...	0·17	0·13	0·22	0·14	4·12
120·	35·0	...	0·30	0·31	0·35	0·32	4·34	440·	129·0	...	0·10	0·13	0·15	0·14	4·11
160·	47·0	...	0·30	0·27	0·35	0·28	4·28	480·	141·0	...	0·10	0·10	0·15	0·11	4·09
200·	58·5	...	0·27	0·23	0·32	0·24	4·25	520·	153·5	...	0·10	0·09	0·15	0·10	4·07
240·	70·5	...	0·20	0·20	0·25	0·21	4·20	560·	165·5	...	0·07	...	0·12	...	4·06

2nd Aug., 1837. WAVE II. Depth 4 inches.

Created by Reservoir A. Volume of added fluid = 152·5 inches.
Transits observed directly at Index γ, without reflection.
Statical level observed at $\left\{ \begin{array}{l} \gamma = -\ 0{\cdot}20 \\ \delta = -\ 0{\cdot}12 \end{array} \right\}$ Corrected statical depth = 3·812 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
...	...	...	0·50	0·60	0·70	0·72	...	240·	70·3	...	0·10	0·10	0·30	0·22	4·11
00·	0·0	...	0·50	0·51	0·70	0·63	4·50	280·	82·2	...	0·07	0·07	0.27	0·19	4·07
40·	11·5	...	0·47	0·42	0·67	0·54	4·48	320·	95·0	...	0·07	0·03	0·27	0·15	4·06
80·	23·0	...	0·37	0·35	0·57	0·47	4·40	360·	107·5	...	0·00	·00	0·20	0·12	4·01
120·	35·0	...	0·30	0·27	0·50	0·39	4·32	400·	119·5	...	0·00	–·02	0·20	0·10	3·98
160·	45·0	...	0·27	0·20	0·47	0·32	4·26	440·	131·0	...	–·05	–·07	0·15	0·03	3·96
200·	58·0	...	0·17	0·14	0·37	0·29	4·18	580·	...	...	...	...	...	...	...

2nd Aug., 1837. WAVE III. Depth 4 inches.

Created by Reservoir A. Volume of added fluid = 137·3 inches.
Transits observed directly at Index γ, without reflection.
Statical level observed at $\left\{ \begin{array}{l} \gamma = -\ 0{\cdot}13 \\ \delta = -\ 0{\cdot}07 \end{array} \right\}$ Corrected statical depth = 3·872 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
...	...	...	0·47	0·52	0·60	0·59	...	200·	60·0	...	0·17	0·17	0·30	0·24	4·16
0·	0·0	0·0	0·40	0·47	0·53	0·54	4·45	240·	71·25	...	0·10	0·15	0·23	0·22	4·12
40·	12·0	...	0·37	0·39	0·50	0·46	4·40	280·	83·5	...	0·10	0·11	0·23	0·18	4·10
80·	23·75	...	0·30	0·31	0·43	0·38	4·33	320·	96·0	...	0·07	0·10	0·20	0·17	4·08
120·	35·5	...	0·22	0·22	0·35	0·29	4·26	360·	107·5	...	0·05	0·09	0·18	0·16	4·05
160·	47·75	...	0·20	0·19	0·33	0·26	4·18	400·	119·5	...	0·02	0·07	0·15	0·14	4·02

2nd Aug., 1837. **WAVE IV.** Depth 4 inches.

Created by Reservoir A. Volume of fluid added = 152·5 inches.
Transits observed directly at Index γ, without reflection.

Statical level observed at $\left\{\begin{array}{l}\gamma = -0{\cdot}05\\ \delta = -0{\cdot}00\end{array}\right\}$ Corrected statical depth = 3·95.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
...	...	...	0·55	0·62	0·60	0·62	...	400.	120·0	...	0·20	0·19	0·15	0·19	4·15
0·	0·	0·	0·55	0·58	0·60	0·58	4·56	440.	132·5	...	0·15	0·15	0·10	0·15	4·13
40·	12·0	...	0·50	0·49	0·55	0·49	4·53	480.	145·0	...	0·15	0·14	0·10	0·14	4·10
80·	24·0	...	0·45	0·41	0·50	0·41	4·46	520.	157·5	...	0·15	0·13	0·10	0·13	4·09
120·	35·5	...	0·37	0·37	0·42	0·37	4·39	560·	170·0	...	0·15	0·13	0·10	0·13	4·09
160·	47·5	...	0·30	0·30	0·35	0·30	4·33	800·	182·5	...	0·15	0·13	0·10	0·13	4·09
200·	59·5	...	0·30	0·26	0·35	0·26	4·28	840.	195·0	...	0·12	0·11	0·07	0·11	4·08
240·	71·5	...	0·27	0·21	0·32	0·21	4·26	880.	206·5	...	0·12	0·10	0·07	0·10	4·07
280·	83·25	...	0·20	0·20	0·25	0·20	4·21	1020·	219·0	...	0·12	0·10	0·07	0·10	4·07
320·	95·25	...	0·20	0·20	0·26	0·20	4·18	1060·	231·5	...	0·10	0·10	0·06	0·10	4·06
360·	107·5	...	0·15	0·19	0·20	0·19	4·17	1100·	244·0	...	0·10	0·10	0·05	0·10	4·05

3rd Aug., 1837. **WAVE V.** Depth 4 inches.

Generated from Reservoir A. Volume of fluid added = 152·5 inches.
Transits observed by the reflected image at the Central Station.
Observers α Glover, β Patrick, γ Hamil, δ Donaldson—Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\alpha = -0{\cdot}10\\ \beta = -0{\cdot}00\end{array}\right\}$ Corrected statical depth = 3·922.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
...	...	...	0·47	0·50	0·57	0·50	...	160·	47·5	...	0·22	0·24	0·32	0·24	4·23
...	...	...	0·47	0·50	0·57	0·50	4·46	200·	59·5	...	0·20	0·22	0·30	0·22	4·21
0·	0·	...	0·42	0·48	0·52	0·48	4·43	240·	71·5	...	0·17	0·20	0·27	0·20	4·18
40·	11·5	...	0·42	0·41	0·52	0·41	4·42	280·	83·5	...	0·12	0·17	0·22	0·17	4·15
80·	23·5	...	0·35	0·30	0·45	0·30	4·38	320·	95·0	...	0·10	...	0·20	...	4·12
120·	36·0	...	0·27	0·27	0·37	0·27	4·30	360·	...	...	...	...	...	...	...

3rd Aug., 1837. **WAVE VI.** Depth 4 inches.

Generated from Reservoir A. Volume of fluid added = 228·7 ? inches.
Transits observed by the reflected image at the Central Station.
Observers α Glover, β Patrick, γ Hamil, δ Donaldson—Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\alpha = -0{\cdot}01\\ \beta = +0{\cdot}09\end{array}\right\}$ Corrected statical depth = 4·012.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
...	...	...	0·60	0·...	0·61	...	...	160·	46·5	47·0	0·30	0·47?	0·31	0·26	4·29
...	...	...	0·57	0·...	0·58	...	4·56	200·	58·0?	58·0	0·25	0·38?	0·26	0·21	4·26
0·	0·	0·	0·52	0·60?	0·53	0·51	4·52	240·	70·0	70·0	0·25	0·35?	0·26	0·14	4·24
40·	11·0	11·0	0·45	0·50?	0·46	0·41	4·46	280·	81·5	82·0	0·20	0·30?	0·21	0·11	4·21
80·	23·0	23·0	0·37	0·47?	0·38	0·37	4·37	320·	...	95·0	...	0·23?	...	...	...
120·	35·0	35·0	0·32	0·38?	0·33	0·29	4·32	360·	...	...	...	0·20?	...	...	...

Those marked thus ? were noticed at the time of observation as imperfectly observed.

3rd Aug., 1837. **WAVE VII.** Depth 4 inches.

Generated from Reservoir A. Volume of fluid added = 152·5 inches.
Transits observed by the reflected image at the Central Station.
Observers α Glover, β Patrick, γ Hamil, δ Donaldson—Transit, Russell.
Statical level observed at $\begin{cases} \alpha = +\ 0{\cdot}09 \\ \beta = +\ 0{\cdot}13 \end{cases}$ Corrected statical depth = 4·07.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
...	...	...	0·62	0·72	0·53	0·59	...	240·	69·5	70·0	0·30	0·30	0·21	0·17	4·26
...	...	...	0·60	0·70	0·51	0·57	4·62	280·	81·0	82·0	0·30	0·30	0·21	0·17	4·26
0·	0·	0·	0·57	0·62	0·48	0·49	4·58	320·	93·0	93·0	0·27	0·29	0·18	0·16	4·23
40·	11·0	12·0	0·50	0·57	0·41	0·44	4·52	360·	104·5	105·0	0·25	0·27	0·16	0·14	4·21
80·	22·5	27·5?	0·40	0·54	0·31	0·41	4·46	400·	116·5	116·5	0·25	0·25	0·16	0·12	4·20
120·	34·5	35·0	0·40	0·40	0·31	0·27	4·40	440·	129·0	129·0	0·22	0·23	0·13	0·10	4·18
160·	46·0	47·0	0·37	0·39	0·28	0·26	4·35	480·	140·0	...	0·22	0·23	0·13	0·10	4·18
200·	58·0	58·0	0·35	0·33	0·26	0·20	4·27	520·	152·0	...	...	...	...	...	...

3rd Aug., 1837. **WAVE VIII.** Depth 4 inches.

Generated by impulsion of Sluice. Volume of fluid added = 305· inches.
Transits observed by reflection at the Central Station.
Observers α Glover, β Patrick, γ Hamil, δ Donaldson—Transit, Russell.
Statical level observed at $\begin{cases} \alpha = +\ 0{\cdot}15 \\ \beta = +\ 0{\cdot}20 \end{cases}$ Corrected statical depth = 4·15 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
...	...	..	1·10	1·20	0·95	1·00	...	320·	91·0	90·0	0·47	0·45	0·32	0·25	4·48
0·	0·	0·	1·07	1·13	0·92	9·03	5·10	360·	102·5	103·0	0·42	0·42	0·27	0·22	4·43
40·	11·0	11·0	1·00	1·01	0·85	0·81	5·02	400·	114·0	114·5	0·40	0·40	0·25	0·20	4·40
80·	22·0	22·0	0·90	0·90	0·75	0·70	4·95	440·	125·5	125·0	0·37	0·39	0·22	0·19	4·37
120·	33·5	33·5	0·80	0·80	0·65	0·60	4·85	480·	138·0	137·5	0·37	0·34	0·22	0·14	4·36
160·	44·5	45·0	0·70	0·71	0·55	0·51	4·75	520·	150·0	150·0	0·32	0·30	0·17	0·10	4·33
200·	56·5	56·0	0·70	0·60	0·55	0·40	4·69	560·	162·0	162·0	0·30	0·30	0·15	0·10	4·29
240·	67·5	67·5	0·60	0·58	0·45	0·38	4·61	600·	174·0	174·0	0·30	0·27	0·15	0·07	4·28
280·	79·0	79·5	0·52	0·49	0·37	0·29	4·55	640·	186·0	185·0	0·30	0·26	0·15	0·06	4·27

3rd Aug., 1837. **WAVE IX.** Depth 4 inches.

Generated by impulsion of Sluice.
Transits observed by the reflected image at the Central Station.
Observers α Glover, β Patrick, γ Hamil, δ Donaldson—Transit, Russell.
Statical level observed at $\begin{cases} \alpha = +\ 0{\cdot}15 \\ \beta = +\ 0{\cdot}21 \end{cases}$ Corrected statical depth = 4·15.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
...	...	...	2·00	1·90	1·85	1·69	...	120.	33·5	33·5	1·20	0·90	1·05	0·69	5·15
0·	0·	0·	1·50	1·50	1·35	1·29	5·67	160·	...	...	1·00	0·92	0·85	0·71	4·97
40·	11·0	11·0	1·40	1·35	1·25	1·14	5·46	200·	56·0	56·0	1·00	0·77	0·85	0·56	4·91
80·	22·0	22·0	1·30	1·30	1·15	1·09	5·38	240·	67·5	67·5	0·90	0·69	0·75	0·48	4·81

3rd Aug., 1837. WAVE X. Depth 4 inches.
Generated by impulsion of Sluice. Very imperfectly observed.
Transits observed by the reflected image at the Central Station.
Observers α Glover, β Patrick, γ Hamil, δ Donaldson—Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\alpha = +0{\cdot}15\\ \beta = +0{\cdot}21\end{array}\right\}$ Corrected statical depth = 4·15.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ′ in.	δ′ in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ′ in.	δ′ in.	in.
...	...	...	2·00	1·90	1·85	1·69	...	120·	33·5	33·5	1·20	0·90	1·05	0·69	5·15
0·	0·	0·	1·50	1·50	1·35	1·29	5·67	160·	...	...	1·00	0·92	0·85	0·71	4·97
40·	11·0	11·0	1·40	1·35	1·25	1·14	5·46	200·	56·0	56·0	1·00	0·77	0·85	0·56	4·91
80·	22·0	22·0	1·30	1·30	1·15	1·09	5·38	240·	67·5	67·5	0·90	0·69	0·75	0·48	4·81

4th Aug., 1837. WAVE XI. Depth 4 inches.
Generated by detached Chamber B. Nimmo ops. Volume = 225·4 inches.
Transits observed by the reflected image at the Central Station.
Observers α Glover, β Patrick, γ Hamil, δ Donaldson—Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\alpha = -0{\cdot}22\\ \beta = -0{\cdot}03\end{array}\right\}$ Corrected statical depth = 3·90.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ′ in.	δ′ in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ′ in.	δ′ in.	in.
0·	0·0	0·0	0·32	0·20	0·54	0·23	4·28	80·	...	24·0	0·20	0·14	0·42	0·17	4·20
40·	...	12·0	0·22	0·19	0·44	0·22	4·23	120·	...	35·5	0·19	0·11	0·41	0·14	4·17

4th Aug., 1837. WAVE XII.* Depth 4 inches.
Generated by detached Chamber B. Nimmo ops. Volume = 341·6 inches.
Transits observed by the reflected image at the Central Station.
Observers α Glover, β Patrick, γ Hamil, δ Donaldson—Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\alpha = -0{\cdot}15\\ \beta = -0{\cdot}01\end{array}\right\}$ Corrected statical depth = 3·95.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ′ in.	δ′ in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ′ in.	δ′ in.	in.
0·	0·	0·	0·90	1·05	1·05	1·06	...	240·	...	54·5	0·47	0·56	0·62	0·57	4·50
40·	...	11·5	0·87	1·05	1·02	1·06	4·99	280·	...	64·5	0·40	0·43	0·55	0·44	4·45
80·	...	21·0	0·80	0·95	0·95	0·96	4·90	320·	...	73·5	0·22	0·37	0·37	0·38	4·32
120·	...	29·5	0·70	0·80	0·85	0·81	4·78	360·	...	83·0	0·20	0·32	0·35	0·33	4·29
160·	...	37·0	0·65	0·70	0·80	0·71	4·71	400·	...	92·0	0·17	0·29	0·32	0·30	4·26
200·	...	43·5	0·55	0·57	0·70	0·58	4·59	440·	...	102·5	0·15	...	0·30	...	4·25

4th Aug., 1837. WAVE XIII. Depth 4 inches.
Generated by detached Chamber B. Nimmo ops. Volume = 278·9 inches.
Transits observed by the reflected image at the Central Station.
Observers α Glover, β Patrick, γ Hamil, δ Donaldson—Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\alpha = -0{\cdot}22\\ \beta = -0{\cdot}04\end{array}\right\}$ Corrected statical depth = 3·90.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ′ in.	δ′ in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ′ in.	δ′ in.	in.
0·	0·0	0·0	0·60?	...	0·82?	...	...	200·	58·0	57·5	0·27	0·33	0·49	0·37	4·33
40·	11·5	11·5	0·62	0·65	0·84	0·69	4·66	240·	...	69·0	0·19	0·25	0·41	0·29	4·25
80·	23·0	23·0	0·57	0·57	0·79	0·61	4·63	280·	...	80·5	0·10	0·22	0·32	0·26	4·19
120·	35·0	34·5	0·50	0·43	0·72	0·47	4·50	320·	...	93·0	...	0·20	...	0·24	4·14
160·	46·0	46·0	0·35	0·40	0·57	0·44	4·40	360·	...	...	...	...	...	...	...

* Some singular error in time runs through this line of indication.

4th Aug., 1837. **WAVE XIV.** Depth 4 inches.

Generated by detached Chamber B. Nimmo op. Volume = 430·4 inches.
Transits observed by the reflected image at the Central Station.
Observers α Glover, β Patrick, γ Hamil, δ Donaldson—Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\alpha = -0{\cdot}22\\ \beta = -0{\cdot}05\end{array}\right\}$ Corrected statical depth = 3·89.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·	0·	1·15	1·30	1·37	1·35	5·25	160·	43·0	43·5	0·80	0·93	1·02	0·98	4·89
40·	11·0	10·5	1·25	1·25	1·47	1·30	5·21	200·	55·0	55·0	0·70	0·65	0·92	0·70	4·70
60·	21·0	21·5	1·17	1·05	1·29	1·10	5·09	240·	66·5	66·0	0·50	0·63	0·72	0·68	4·59
120·	32·0	32·0	0·97	0·95	1·19	1·00	4·99	280·	78·5	78·5	0·55	...	0·77	...	...

4th Aug., 1837. **WAVE XV.*** Depth 4 inches.

Generated by detached Chamber B. Nimmo op. Volume of fluid added = 532·8 inches.
Transits observed by the reflected image at the Central Station.
Observers α Glover, β Patrick, γ Hamil, δ Donaldson—Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\alpha = -0{\cdot}25\\ \beta = -0{\cdot}07\end{array}\right\}$ Corrected statical depth = 3·87.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	1·20	1·33	1·45	1·40	5·30	280·	76·0	77·0	...	0·61	...	0·68	4·55
40·	10·0	10·0	1·30	1·29	1·55	1·36	5·32	320·	88·5	89·0	0·30	0·49	0·55	0·56	4·43
80·	21·0	20·5	1·15	1·20	1·40	1·27	5·20	360·	100·0	100·0	0·22	0·44	0·47	0·51	4·36
120·	31·5	31·5	1·10	1·00	1·35	1·07	5·03	400·	...	111·5	0·22	0·42	0·47	0·49	4·35
160·	42·5	42·5	0·90	0·96	1·15	1.04	4·96	440·	...	124·0	0·19	0·40	0·44	0·47	4·32
200·	54·0	54·0	0·75	0·65	1·00	0·72	4·68	480·	...	136·0	0·15	0·32	0·40	0·39	4·27
240·	65·5	65·0	0·62	0·61	0·77	0·68	4·60	520·	...	150·0	0·10	0·25	0·35	0·32	4·20

* Very successfully observed up to 100.

4th Aug., 1837. **WAVE XVI.** Depth 4 inches.

Generated by detached Chamber B. Nimmo op. Volume of fluid added = 982·3 inches.
Transits observed by the reflected image at the Central Station.
Observers α Glover, β Patrick, γ Hamil, δ Donaldson—Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\alpha = -0{\cdot}37\\ \beta = -0{\cdot}20\end{array}\right\}$ Corrected depth = 3·74 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	2·10*	1·4	2·47	1·60	5·77	160·	42·5	43·0	0·70	0·85	1·07	0·95	4·75
40·	10·0	10·5	2·3	1·3	2·69	1·50	5·83	200·	53·5	54·0	0·80	0·65	1·17	0·85	4·75
80·	20·5	21·0	...	1·2	...	1·40	...	240·	65·0	65·5	...	0·65	...	0·85	4·75
120·	31·0	31·5	1·0	1·25	1·37	1·45	5·05	280·	77·0	77·5	0·50	...	0·87	...	...

* This wave reached its maximum height and broke between γ and δ.

4th Aug., 1837. **WAVE XVII.** Depth 4 inches.

Generated by detached Chamber B. Nimmo op. Volume of fluid added = 785·68 inches.
Transits observed by the reflected image at the Central Station.
Observers α Glover, β Patrick, γ Hamil, δ Donaldson—Transit, Russell.

Statical level observed at $\left\{\begin{matrix}\alpha = -0{\cdot}35\\ \beta = -0{\cdot}15\end{matrix}\right\}$ Corrected statical depth = 3·78 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	1·80*	...	2·17	...	...	200·	55·0	55·5	0·80	0·61	1·02	0·83	4·71
40·	10·5	10·5	2·00	1·20	2·37	1·40	5·66	240·	66·5	66·0	0·67	0·57	0·89	0·79	4·62
80·	21·5	21·5	1·10	1·10	1·47	1·10	5·06	280·	78·5	77·5	0·52	0·52	0·74	0·74	4·52
120·	32·5	32·0	0·87	1·02	1·24	1·22	5·01	320·	...	...	0·50	...	0·72	...	4·50
160·	44·0	44·0	0·80	0·65	1·17	0·85	4·80	360·	...	...	...	...	...	...	...

4th Aug., 1837. **WAVE XVIII.** Depth 4 inches.

Generated by detached Chamber B. Nimmo op. Volume of fluid added = 1127·2 inches.
Transits observed by the reflected image at the Central Station.
Observers α Glover, β Patrick, γ Hamil, δ Donaldson—Transit, Russell.

Statical level obs. at commencement $\left\{\begin{matrix}\alpha = -0{\cdot}50\\ \beta = -0{\cdot}35\end{matrix}\right\}$ Corrected statical depth = 3·60 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	3·5*	1·6	3·5	1·95	...	160·	38·5	45·0	1·20	0·40	1·70	0·75	...
40·	11·0	11·0	...	1·1	...	1·45	...	200·	55·0	56·0	1·10	0·50	1·60	0·85	...
80·	20·5	21·5	...	0·95	...	1·30	...	240·	...	...	...	...	...	...	...
120·	31·5	33·0	1·40	0·70	1·90	1·05	...	280·	...	...	...	...	...	...	...

* This wave reached its maximum height and broke between γ and δ.

5th Aug., 1837. **WAVE XIX.*** Depth 4 inches.

Generated by protrusion of solid parallelopipedon C. Volume = 276·3 inches.
Transits observed by reflection as formerly in the positive wave.
Transits observed directly, and at successive transits in the negative wave.
Observers β Patrick, γ Hamil, δ Donaldson—Transit, Russell.

Statical level observed at $\left\{\begin{matrix}\gamma = -0{\cdot}10\\ \delta = +0{\cdot}05\end{matrix}\right\}$ Corrected statical depth = 3·95 inches.

A	B		C		D		E	A	B		C		D		E
feet·	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	...	0·0	1·5	1·4?	1·60	1·4?	...	280·	...	76·5	0·60	0·80	0·70	0·75	4·67
40·	...	10·5	1·30	1·45	1·40	1·40	5·40	320·	...	88·0	0·55	0·67	0·65	0·62	4·58
80·	...	21·0	1·20	1·30	1·30	1·25	5·22	360·	...	99·5	0·50	0·65	0·60	0·60	4·55
120·	...	31·5	1·10	1·25	1·20	1·20	5·15	400·	...	111·0	0·45	0·61	0·55	0·56	4·50
160·	...	42·0	0·95	1·15	1·05	1·10	5·02	440·	...	122·5	0·37	0·52	0·47	0·47	4·42
200·	...	52·5	0·70	1·01	0·80	0·96	4·83	480·	...	136·5	0·35	0·49	0·45	0·44	4·40
240·	...	64·5	0·60	0·97	0·70	0·92	4·76	520·	See	note*	...	...	...	...	...

* This wave was unusually perfect in its form, and was observed with much precision and care; there was no secondary wave.

5th Aug., 1837. WAVE XX. Negative. Depth 4 inches.

Generated by removing solid parallelopipedon C. Volume = 276·3 inches.
Observed directly and timed at gauges γ and δ.
Observers β Patrick, γ Hamil, δ Donaldson—Transit, Russell.
Statical level observed at $\left\{\begin{matrix}\gamma = +\,0{\cdot}05\\ \delta = +\,0{\cdot}21\end{matrix}\right\}$ Corrected statical depth = 4·10 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	−0·80	...	−0·85	...	...	95·7	...	32·5	...	−0·20	...	−0·41	3·77
14·62	...	6·0	...	−0·3	...	−0·51	3·42	115·7	...	...	−0·20	...	−0·25	...	3·77
35·7	...	...	−0·30	...	−0·35	...	3·67	135·7	...	−45·5	...	−0·20	...	−0·41	3·77
55·7	...	19·5	...	−0·20	...	−0·41	3·72	155·7	...	...	...	...	...	...	...
75·7	26·5	...	−0·20	...	−0·25	...	3·77	175·7	...	59·0	...	...	...	...	...

5th Aug., 1837. WAVE XXI. Depth 4 inches.

Generated by protrusion of solid C. Volume = 276·3 inches.
Observed directly and timed at gauges γ and δ.
Transits observed directly and at successive transits in the negative wave.
Observers β Patrick, γ Hamil, δ Donaldson—Transit, Russell.
Statical level observed at $\left\{\begin{matrix}\gamma = +\,0{\cdot}05\\ \delta = +\,0{\cdot}13\end{matrix}\right\}$ Corrected depth = 4·06 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	1·50	1·42	1·45	1·29	...	200·	...	53·0	0·70	1·03	0·65	0·90	4·83
40·	...	10·0	1·30	1·40	1·25	1·27	5·37	240·	...	64·5	0·70	0·96	0·65	0·83	4·82
80·	...	20·5	1·20	1·29	1·20	1·16	5·27	280·	...	76·0	0·70	0·85	0·65	0·72	4·78
120·	...	30·1	1·10	1·20	1·05	1·07	5·17	320·	...	80·0	...	...	...	...	...
160·	...	42·1	0·90	1·05	0·85	0·92	5·08	360·	...	...	...	...	...	...	...

5th Aug., 1837. WAVE XXII. Negative. Depth 4 inches.

Generated by removing solid parallelopipedon C. Volume = 276·3 inches.
Observed directly and timed at gauges γ and δ.
Observers β Patrick, γ Hamil, δ Donaldson—Transit, Russell.
Statical level observed at $\left\{\begin{matrix}\gamma = +\,0{\cdot}05\\ \delta = +\,0{\cdot}21\end{matrix}\right\}$ Corrected depth = 4·10 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	− 1·0	...	−1·05	...	...	95·7	...	...	...	− 0·1	...	− 0·36	3·75
14·62	...	5·5	...	−0·3	...	−0·51	3·32	115·7	...	...	− 0·3	...	− 0·35	...	3·75
35·7	...	13·5	− 0·3	...	−0·35	...	3·67	135·7	...	...	...	− 0·07	...	− 0·28	3·79
55·7	...	20·0	...	−0·15	...	−0·36	3·75	155·7	...	...	...	...	...	...	...
75·7	...	...	− 0·3	...	−0·35	...	3·75	175·7	...	...	...	− 0·05	...	− 0·26	...

5th Aug., 1837. **WAVE XXIII.** Depth 4 inches.

Generated by Chamber D, from a height of 19 inches. Volume = 683·7 inches.
Transits observed by reflection as formerly in the positive wave. *
Transits observed directly, and at successive transits in the negative wave.
Observers β Patrick, γ Hamil, δ Donaldson—Transit, Russell.

Statical level observed at $\left\{ \begin{array}{l} \gamma = 0{\cdot}25 \\ \delta = 0{\cdot}10 \end{array} \right\}$ Corrected depth = 3·85 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	1·30	1·30	1·55	1·40	5·32	200·	...	55·5	0·75	0·75	1·00	0·85	4·77
40·	...	11·5	1·10	1·25	1·25	1·35	5·15	240·	...	66·5	0·60	0·70?	0·85	0·80	4·67
80·	...	21·5	0·90	1·33	1·15	1·43	5·14	280·	...	79·0	0·50	0·54	0·75	0·64	4·55
120·	...	32·5	0·90	1·23	1·15	1·33	5·09	320·	...	91·0	0·50	0·45	0·75	0·55	4·50
160·	...	43·5	0·80	0·92	1·05	1·02	4·88	360·	...	...	...	...	...	...	...

* This wave broke down immediately into two waves of nearly equal height.

5th Aug., 1837. **WAVE XXIV.** Depth 4 inches.

Generated by Chamber D, from a height of 19 inches. Height = 20 inches. Volume = 719·3 inches.
Transits observed by reflection as formerly in the positive wave.
Transits observed directly, and at successive transits in the negative wave.
Observers β Patrick, γ Hamil, δ Donaldson—Transit, Russell.

Statical level observed at $\left\{ \begin{array}{l} \gamma = -0{\cdot}25 \\ \delta = -0{\cdot}10 \end{array} \right\}$ Corrected depth = 3·85 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	...	0·0	1·30	...	1·55	...	...	200	...	56·5	0·70	0·50?	1·95	0·60?	...
40·	...	11·5	1·00	1·20	1·25	1·30	5·12	240	...	68·5	0·50	0·45?	0·75	0·55?	...
80·	...	22·0	0·90	1·15	1·15	1·25	5·05	280	...	...	0·45	...	0·70	...	...
120·	...	33·0	0·70	0·80?	1·95	0·90?	...	320	...	92·0	0·30	...	0·55	...	...
160·	...	44·5	0·70	0·65?	1·95	0·75?	...	360	...	...	...	...	...	...	...

5th Aug., 1837. **WAVE XXV.** Depth 3 inches.

Generated protrusion of solid parallelopipedon C. Volume = 208·3 inches.
Transits observed by reflection at the Central Station.
Observers β Patrick, γ Hamil, δ Donaldson—Transit, Russell.

Statical level observed at $\left\{ \begin{array}{l} \gamma = +0{\cdot}05 \\ \delta = +0{\cdot}20 \end{array} \right\}$ Corrected statical depth = 3·08 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	...	0·0	1·50	1·30	1·45	1·10	4·35	200·	...	61·5	0·57	0·70	0·52	0·60	3·64
40·	...	11·5	1·10	1·15	1·05	0·95	4·08	240·	...	75·0	0·47	0·60	0·42	0·50	3·54
80·	...	23·5	0·90	1·13	0·85	0·93	3·97	280·	...	89·0	0·40	0·53	0·35	0·43	3·49
120·	...	36·0	0·85	...	0·80	...	3·88	320·	...	...	0·37	...	0·32	...	3·38
160·	...	48·5	0·70	0·70	0·65	0·50	3·65	360·	...	116·0	0·29	...	0·24	...	3·32

5th Aug., 1837. **WAVE XXVI.** Depth 3 inches.

Generated protrusion of solid parallelopipedon C. Volume = 208·3 inches.
Transits observed by reflection at the Central Station.
Observers β Patrick, γ Hamil, δ Donaldson—Transit, Russell.
Statical level observed at $\left\{ \begin{matrix} \gamma = +0\cdot05 \\ \delta = +0\cdot20 \end{matrix} \right\}$ Corrected statical depth = 3·08 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	...	0·0	1·00	1·12	0·95	0·92	4·02	360·	...	116·0	0·30	0·39	0·25	0·19	3·29
40·	...	12·0	0·90	1·04	0·85	0·84	3·92	400·	...	129·5	0·20	0·39	0·15	0·19	3·25
80·	...	24·5	0·80	0·95	0·75	0·75	3·83	440·	...	144·0	0·20	0·35	0·15	0·15	3·23
120·	...	37·0	0·75	0·70	0·70	0·50	3·68	480·	...	157·5	0·17	0·32	0·12	0·12	3·20
160.	...	49·5	0·60	0·62	0·55	0·42	3·56	520·	...	171·0	0·15	0·30	0·10	0·20	3·23
200·	...	62·5	0·50	0·60	0·45	0·40	3·50	560·	...	185·0	0·15	0·30	0·10	0·20	3·23
240·	...	75·5	0·40	0·55	0·35	0·35	3·43	600·	...	199·0	0·12	0·30	0·07	0·20	3·22
280·	...	89·0	0·37	0·47	0·32	0·27	3·37	640·	...	212·0?	0·12	0·30	0·07	0·20	3·21
320·	...	102·5	0·30	0·40	0·25	0·20	3·30	680·	...	...	...	...	...	...	...

7th Aug., 1837. **WAVE XXVII.** Depth 1 inch.

Generated by solid C. projected to bottom. Volume added = 88·3 inches.
Transits observed successively without omission at Central Station.
Observers α Russell, β Patrick, γ Hamil, δ Donaldson—Transit, Russell.
Statical level observed at $\left\{ \begin{matrix} \gamma = 0\cdot000 \\ \delta = 0\cdot000 \end{matrix} \right\}$ True statical depth = 1·00 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	0·30	...	0·30	...	1·30	60·	34·0	34·5	...	0·05	...	0·05	1·05
20·	11·0	10·5	...	0·13	...	0·13	1·13	80·	45·0	...	0·05	...	0·05	...	1·05
40·	21·0	22·0	0·10	...	0·10	...	1·10	100·	...	57·0	...	0·03	...	0·03	1·03

7th Aug., 1837. **WAVE XXVIII.** Depth 1 inch.

Generated by solid C. projected to bottom. Volume added = 88·3 inches.
Transits observed successively without omission at Central Station.
Observers, α Russell, β Patrick, γ Hamil, δ Donaldson—Transit, Russell.
Statical level observed at $\left\{ \begin{matrix} \gamma = 0\cdot000 \\ \delta = 0\cdot000 \end{matrix} \right\}$ True statical depth = 1·00 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	0·29	...	0·29	...	1·29	60·	34·0	34·5	...	0·03	...	0·03	1·03
20·	10·5	...	...	0·11	...	0·11	1·11	80·	46·0	47·0	0·02	...	0·02	...	1·02
40·	22·5	23·0	0·19	...	0·19	...	1·19	100·	...	...	...	0·02	...	0·02	1·02

7th Aug., 1837. WAVE XXIX. Depth 1 inch.

Generated by solid C. projected to bottom. Volume added = 88·3 inches.
Transits observed successively without omission at Central State.
Observers, α Russell, β Patrick, γ Hamil, δ Donaldson—Transit, Russell.
Statical level observed at $\left\{ \begin{array}{l} \gamma = 0{\cdot}000 \\ \delta = 0{\cdot}000 \end{array} \right\}$ True statical depth = 1·00 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	0·30	...	0·30	...	1·3	80·	46·5	46·0	0·09	...	0·09	...	1·09
20·	10·7	11·0	...	0·12	...	0·12	1·12	100·	58·0	58·0	...	0·04	...	0·04	1·04
40·	22·5	22·5	0·10	...	0·10	...	1·10	120·	70·5	70·5	0·02	...	0·02	...	1·02
60·	34·5	34·0	...	0·05	...	0·05	1·05	140·	...	...	...	0·02	...	0·02	1·02

7th Aug., 1837. WAVE XXX. Negative. Depth 1 inch.

Generated by subtraction of solid C.
Transits observed successively without omission at Central Station.
Observed and timed at γ and δ. Depth 1·0 inch.
Statical level observed at $\left\{ \begin{array}{l} \gamma = 0{\cdot}000 \\ \delta = 0{\cdot}000 \end{array} \right\}$ True statical depth = 1·00 inch.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	−0·1	...	−0·1	...	0·9	56·7	39·5	39·5	...	−0·04	...	−0·04	0·96
14·62	9·5	9·5	...	−0·05	...	−0·05	0·95	75·7	...	...	...	...	...	...	...
35·7	24·5	24·5	−0·02	...	−0·02	...	0·98	95·7	...	...	...	...	...	...	...

7th Aug., 1837. WAVE XXXI. Depth 1 inch.

Generated by solid C. projected to bottom. Volume added = 88·3 inches.
Transits observed successively without omission at Central State.
Observers, α Russell, β Patrick, γ Hamil, δ Donaldson—Transit, Russell.
Statical level observed at $\left\{ \begin{array}{l} \gamma = 0{\cdot}000 \\ \delta = 0{\cdot}000 \end{array} \right\}$ True statical depth = 1·00 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	0·35	...	0·35	....	1·35	60·	...	...	...	0·05	...	0·05	1·05
20·	11·0	11·0	...	0·15	...	0·15	1·15	80·	...	...	...	...	...	...	...
40·	22·5	22·5	0·09	...	0·09	...	1·09	100·	...	...	...	...	...	...	...

7th Aug., 1837. WAVE XXXII. Negative. Depth 1 inch.

Generated by subtraction of solid C.
Transits observed successively without omission at Central Station.
Observed and timed at γ and δ. Depth 1·0 inch.

Statical level observed at $\left\{ \begin{array}{l} \gamma = 0{\cdot}000 \\ \delta = 0{\cdot}000 \end{array} \right\}$ True statical depth = 1·00 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	−0·10	...	−0·10	...	0·90	55·7	37·5	...	...	−0·06	...	−0·06	0·94
[illegible]·62	9·0+	...	...	−0·07	...	−0·07	0·93	75·7	52·0	...	−0·02	...	−0·02	...	0·98
[illegible]·7	25·5	...	−0·07	...	−0·07	...	0·93	95·7	65·0	...	...	−0·04	...	−0·04	0·96

7th Aug., 1837. WAVE XXXIII. Depth 1 inch.

Generated by Chamber B. Volume of added fluid = 68·32 inches.

Statical level observed at $\left\{ \begin{array}{l} \gamma = 0{\cdot}15 \\ \delta = 0{\cdot}15 \end{array} \right\}$ Correct depth = 1·15 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	0·70	...	0·55	...	1·70	60·	32·0	32·0	...	0·25	...	0·1	1·25
20·	10·0	10·0	...	0·35	...	0·2	1·35	80·	...	...	...	...	...	...	...
40·	21·0	21·0	0·30	...	0·15	...	1·30	100·	...	...	...	0·22	...	0·07	1·22

7th Aug., 1837. WAVE XXXIV. Depth 1 inch.

Generated by detached Chamber B. Volume of added fluid = 1024·8 inches.

Statical level observed at $\left\{ \begin{array}{l} \gamma = 0{\cdot}19 \\ \delta = 0{\cdot}19 \end{array} \right\}$ Corrected depth = 1·19 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	1·70	...	1·51	...	2·70	80·	35·5	37·0	0·40	...	0·21	...	1·40
20·	7·0	7·5	...	1·05	...	0·86	2·05	100·	46·0	47·5	...	0·30	...	0·11	1·30
40·	16·5	18·0	0·70	...	0·51	...	1·70	120·	57·0	58·5	0·32	...	0·13	...	1·32
60·	25·5	26·5	...	...	...	...	...	140·	...	...	...	0·25	...	0·06	1·25

7th Aug., 1737. WAVE XXXV. Depth 1 inch.

Generated by detached Chamber B. Volume of fluid added = 666·1 inches.

Statical level observed at $\left\{ \begin{array}{l} \gamma = 0{\cdot}37 \\ \delta = 0{\cdot}25 \end{array} \right\}$ Corrected depth = 1·31 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	2·10	...	1·79	...	3·10	80·	...	35·0	0·80	...	0·43	...	1·80
20·	...	8·0	...	1·50	...	1·19	2·50	100·	...	44·5	...	0·5	...	0·25	1·50
40·	...	17·0	1·10	...	0·79	...	2·10	120·	...	54·5	0·70	...	0·33	...	1·70
60·	...	25·5	...	0·75	...	0·44	1·75	140·	...	64·0	...	0·50	...	0·25	1·50

7th Aug., 1837. **WAVE XXXVI.** Depth 2 inches.

Generated by detached Chamber B. Volume of fluid added = 631·9 inches.

Statical level observed at $\left\{\begin{array}{l}\gamma = -\cdot 15\\ \delta = -\cdot 05\end{array}\right\}$ Corrected depth = 1·90 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	1·40	...	1·55	...	3·45	120·	45·5	45·5	0·20	...	0·35	...	2·25
20·	6·5	7·5	...	...	...	...	...	140·	54·0	53·5	...	...	...	...	...
40·	14·0	15·0	0·40	...	0·55	...	2·45	160·	62·5	65·0?	0·12	...	0·27	...	2·17
60·	21·0	22·5	...	...	...	...	...	180·	71·0	72·5	...	...	...	...	...
80·	29·5	30·0	0·30	...	0·45	...	2·35	200·	80·5	80·0	0·09	...	0·24	...	2·14
100·	37·0	...	...	...	...	...	...	220·	...	...	...	...	...	...	...

7th Aug., 1837. **WAVE XXXVII.** Depth 3 inches.

Generated by sluice from Reservoir A. Volume of fluid added = 152·5 inches.
Observers, time, α Russell, γ Patrick, δ Grant.

Statical level observed at $\left\{\begin{array}{l}\gamma = 0{\cdot}03\\ \delta = 0{\cdot}00\end{array}\right\}$ Depth = 3·0 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	...	1·0	...	1·0	4·0	140·	43·0	...	0·70	...	0·65	...	3·65
20·	6·0	...	1·1	...	1·05	...	4·05	160·	49·0	...	...	...	...	...	...
40·	12·0	...	...	0·9	...	0·9	3·90	180·	56·0	...	0·60	...	0·55	...	3·55
60·	18·0	...	0·97	...	0·92	...	3·92	200·	62·0	...	...	...	...	...	...
80·	24·25	...	...	...	...	...	...	220·	69·0	...	0·57	...	0·52	...	3·52
100·	30·0	...	0·87	...	0·82	...	3·82	240·	75·0	...	...	...	...	...	...
120·	36·5	...	...	...	...	...	...	260·	...	...	0·47	...	0·42	...	3·42

7th Aug., 1837. **WAVE XXXVIII.** Depth 3 inches.

Generated by sluice from Reservoir A. Volume of fluid added = 152·5 inches.
Observers, time, α Russell, γ Patrick, δ Grant.

Statical level observed at $\left\{\begin{array}{l}\gamma + 0{\cdot}05\\ \delta \quad\; 0{\cdot}00\end{array}\right\}$ Depth 3·00 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
...	...	...	1·30	0·95	1·25	0·95	4·10	140·	...	...	...	0·40	...	0·40	3·40
0·	0·0	...	1·00	...	0·95	...	3·95	160·	50·0?	...	...	...	...	...	...
20·	6·25	...	...	0·80	...	0·80	3·80	180·	56·5	...	...	0·35	...	0·35	3·35
40·	12·5	...	0·85	...	0·80	...	3·80	200·	63·5	...	...	...	...	...	...
60·	18·5	...	...	0·70	...	0·70	3·70	220·	70·0	...	...	0·30	...	...	3·30
80·	25·0	...	0·55	...	0·50	...	3·50	240·	76·5	...	...	...	...	...	...
100·	31·25	...	...	0·55	...	0·55	3·55	260·	...	...	...	...	...	...	...
120·	37·5	...	0·45	...	0·40	...	3·40	280·	...	...	...	...	...	...	...

7th Aug., 1837. **WAVE XXXIX.** Depth 3 inches.

Generated by protrusion of solid parallelopipedon C. Volume = 264·9 inches.

Statical level observed at $\left\{ \begin{array}{l} \gamma = 0{\cdot}00 \\ \delta = 0{\cdot}03 \end{array} \right\}$ Depth = 2·94 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
...	...	...	1·40	0·90	1·40	0·93	4·00	80·	24·5	...	0·87	...	0·87	...	3·81
0·	0·0	0·0	1·1	...	1·10	...	4·04	100·	31·5	...	...	0·70	...	0·73	3·67
20·	6·0	...	...	0·9	...	0·93	3·87	120·	37·5	...	0·675	...	0·67	...	3·61
40·	12·0	...	0·92	...	0·92	...	3·86	140·	44·5	...	...	0·55	...	0·58	3·52
60·	18·2	...	...	0·85	...	0·88	3·82	160·	...	...	...	...	...	...	...

7th Aug., 1837. **WAVE XL.** Depth 3 inches.

Generated by protrusion of solid parallelopipedon C. Volume = 264·9 inches.

Statical level observed at $\left\{ \begin{array}{l} \gamma = 0{\cdot}00 \\ \delta = 0{\cdot}03 \end{array} \right\}$ Corrected depth = 2·94 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
...	...	...	1·1	1·0	1·1	1·03	3·97	200·	63·0	...	0·375	...	0·37	...	3·31
0·	0·0	0·0	1·0	...	1·0	...	3·94	220·	70·25	...	...	0·30	...	0·30	3·27
20·	6·0	...	...	0·9	...	0·93	3·87	240·	76·50	...	0·30	...	0·30	...	3·24
40·	12·0	...	0·975	...	0·97	...	3·91	260·	83·50	...	...	0·25	...	0·28	3·22
60·	18·5	...	...	0·80	...	0·83	3·77	280·	91·00	...	0·20	...	0·20	...	3·14
80·	24·5	...	0·80	...	0·80	...	3·74	300·	98·5	...	...	0·23	...	0·26	3·20
100·	31·0	...	...	0·68	...	0·71	3·65	320·	105·5?	...	0·17	...	0·17	...	3·11
120·	37·0	...	0·675	...	0·67	...	3·61	340·	112·0?	...	...	0·18	...	0·21	3·15
140·	43·5	...	...	0·50	...	0·53	3·47	360·	119·5	...	0·12	...	0·12	...	3·07
160·	50·0	...	0·475	...	0·47	...	3·41	380·	...	...	...	0·15	...	0·18	3·12
180·	57·0	...	...	0·35	...	0·38	3·33	400·	...	...	...	...	...	...	...

7th Aug., 1837. **WAVE XLI.** Depth 3 inches.

Generated by protrusion of solid parallelopipedon C. Volume = 132·4 inches.

Statical level observed at $\left\{ \begin{array}{l} \gamma = 0{\cdot}00 \\ \delta = 0{\cdot}05 \end{array} \right\}$ Corrected depth = 2·94 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
...	...	...	0·8	0·5	0·80	0·55	3·49	220·	78·0	...	...	0·23	...	0·28	3·22
0·	0·0	0·0	0·7	...	0·70	...	3·64	240·	85·0	...	0·20	...	0·20	...	3·14
20·	6·5	...	...	0·55	...	0·60	3·54	260·	91·7	...	...	0·20	...	0·25	3·19
40·	12·5	...	0·625	...	0·62	...	3·56	280·	...	...	0·20	...	0·20	...	3·14
60·	19·5	...	...	0·47	...	0·52	3·46	300·	106·	...	...	0·17	...	0·22	3·16
80·	25·7	...	0·50	...	0·50	...	3·44	320·	113·	...	0·15	...	0·15	...	3·09
100·	33·5	...	...	0·40	...	0·45	3·39	340·	121·	...	...	0·15	...	0·20	3·14
120·	39·5	...	0·40	...	0·40	...	3·34	360·	127·	...	0·12	...	0·12	...	3·06
140·	...	...	...	0·33	...	0·38	3·32	380·	134·	...	...	0·13	...	0·18	3·12
160·	51·0	...	0·32	...	0·32	...	3·26	400·	140·5	...	0·10	...	0·10	...	3·04
180·	57·5	...	...	0·25	...	0·30	3·24	420·	147·5	...	...	...	...	...	...
200·	64·5	...	0·27	...	0·27	...	3·21	440·	...	...	...	...	...	...	...

7th Aug., 1837. **WAVE XLII.** Depth 3 inches.

Generated by protrusion of solid parallelopipedon C. Volume = 264·9 inches.
Statical level observed at $\left\{\begin{matrix}\gamma = 0{\cdot}00\\ \delta = 0{\cdot}03\end{matrix}\right\}$ Depth = 2·94 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
...	...	...	1·50	0·95	1·50	1·00	4·19	160·	51·0	...	0·47	0·40	0·47	0·45	3·40
0·	0·0	0·0	1·50	0·80	1·50	0·85	4·06	200·	64·5	...	0·40	0·33	0·40	0·38	3·33
40·	12·0	...	0·90	0·70	0·90	0·75	3·74	240·	78·5?	...	0·30	0·25	0·30	0·30	3·24
80·	25·0	...	0·75	0·65	0·75	0·70	3·66	280·	...	...	0·20	0·23	0·20	0·28	3·18
120·	38·0	...	0·52	0·47	0·52	0·52	3·46	320·	...	...	...	...	...	...	...

8th Aug., 1837. **WAVE XLIII.** Depth 5 inches.

Generating solid C. projected. Volume = 445·1 inches.
Observers, α Russell, β Patrick, γ Hamil, δ Donaldson, Gen. Nimmo.
Statical level observed at commencement $\left\{\begin{matrix}\gamma = -0{\cdot}05\\ \delta = +0{\cdot}10\end{matrix}\right\}$ Depth = 5·045 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	1·40	1·20	1·45	1·10	6·32	...	...	...	...	...	...	...	...
40·	10·0	10·5	1·20	1·25	1·25	1·15	6·25	440·	90·0	89·5	0·70	0·63	0·75	0·53	5·69
80·	19·5	19·5	1·15	...	1·20	...	6·15	480·	100·2	99·5	0·60	0·55	0·65	0·45	5·60
120·	29·0	28·5	1·02	1·05	1·07	0·95	6·06	520·	...	109·0	0·50	0·55	0·55	0·45	5·55
160·	39·0	38·5	0·87	1·01	0·92	0·96	5·99	560·	...	119·0	0·50	0·47	0·55	0·37	5·51
200·	49·5	49·5	...	0·85	0·90	0·75	5·87	600·	...	130·0	0·45	0·40	0·50	0·30	5·45
240·	59·0	58·5	0·80	0·85	0·85	0·75	5·85	640·	...	141·0	0·40	0·39	0·45	0·29	5·42
360·	69·5	68·5	0·77	0·69	0·82	0·59	5·75	680·	...	151·0	0·35	0·34	0·40	0·24	5·37
400·	79·5	79·0	0·72	0·66	0·77	0·55	5·71	720·	...	162·0	0·30	0·33	0·35	0·23	5·34

8th Aug., 1837. **WAVE XLIV.** Negative depth, 5 inches.

Generating solid withdrawn. Volume subtracted = 445·1 inches.
Observers, α Russell, β Patrick, γ Hamil, δ Donaldson, Gen. Nimmo.
Statical level observed at $\left\{\begin{matrix}\gamma = 0{\cdot}02\\ \delta = 0{\cdot}15\end{matrix}\right\}$ Corrected depth = 5·10 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	−0·9	...	−0·92	...	4·18	55·7	16·5	16·5	...	−0·35	...	−0·50	4·50
14·62	4·0	4·5	...	−0·4	...	−0·55	4·55	75·7	24·0	24·0	−0·30	...	−0·35	...	4·75
35·70	10·5	10·5	−0·4	...	−0·45	...	4·65	95·7	29·0	29·5	...	−0·20	...	−0·35	4·75

8th Aug., 1837. **WAVE XLV.** Depth 5 inches.

Generating solid C projected. Volume added = 445·1 inches.
Observers, α Russell, β Patrick, γ Hamil, δ Donaldson, Gen. Nimmo.

Statical level observed at $\left\{\begin{array}{l}\gamma = -\ 0{\cdot}05 \\ \delta = +\ 0{\cdot}10\end{array}\right\}$ Corrected depth = 5·10 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	1·40	1·45	1·38	1·30	6·44	840·	162·5	163·0	0·35	0·34	0·33	0·19	5·36
40·	9·75	9·50	1·39	1·40	1·37	1·25	6·41	880·	173·0	173·5	0·32	0·30	0·30	0·15	5·32
80·	19·5	19·0	1·30	1·37	1·28	1·22	6·35	920·	...	184·0	0·29	0·30	0·27	0·15	5·31
120·	28·5	29·0	1·29	1·20	1·27	1·05	6·26	960·	...	195·0	0·26	0·29	0·24	0·14	5·29
160·	38·5	39·0	1·15	1·13	1·13	1·00	6·16	1000·	...	205·5	0·25	0·27	0·23	0·12	5·27
200·	48·5	49·0	1·02	1·05	1·00	0·90	6·05	1040·	...	216·5	0·22	0·27	0·20	0·12	5·26
240·	58·5	59·0	0·85	0·85?	0·83	0·70	5·86	1080·	...	227·5	0·22	0·26	0·20	0·11	5·25
280·	68·5	69·0	0·80	0·83	0·78	0·68	5·83	1120·	...	237·5	0·21	0·25	0·19	0·10	5·24
320·	79.0	79·5	0·72	0·77	0·70	0·62	5·76	1160·	...	248·5	0·20	0·23	0·18	0·08	5·23
360·	89·0	89·5	0·70	0·63	0·68	0·48	5·68	1200·	...	259·5	0·19	0·21	0·17	0·06	5·22
400·	99·5	100·0	0·60	0·62	0·58	0·47	5·63	1240·	...	270·0	0·17	0·20	0·15	0·05	5·20
440·	110·0	110·5	0·52	0·51	0·50	0·36	5·52	1280·	...	281·0	0·16	0·20	0·14	0·05	5·19
480·	120·5	121·0	0·50	0·49	0·48	0·34	5·51	1320·	...	291·5	0·15	0·20	0·13	0·05	5·19
520·	131·0	131·5	0·47	0·41	0·45	0·30	5·47	1360·	...	302·5	0·14	0·20	0·12	0·05	5·18
560·	141·5	142·0	0·42	0·39	0·40	0·25	5·42	1400·	...	...	...	...	...	...	...
600·	151·5	152·5	0·37	0·37	0·35	0·20	5·37	1440·	...	...	...	...	...	...	...

8th Aug., 1837. **WAVE XLVI.** Depth 5 inches.

Generating solid C projected. Volume added = 445·1 inches.
Observers, α Russell, β Patrick, γ Hamil, δ Donaldson, Gen. Nimmo.

Statical level observed at $\left\{\begin{array}{l}\gamma = +\ 0{\cdot}02 \\ \delta = +\ 0{\cdot}15\end{array}\right\}$ Corrected depth = 5·10 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	1·60	1·85	1·58	1·70	6·74	280·	...	...	0·92	1·10	0·90	0·95	6·02
40·	9·25	10·0	1·60	1·73	1·58	1·58	6·68	320·	...	78·0	0·90	0·95	0·88	0·80	5·94
80·	18·30	19·0	1·57	1·71	1·55	1·56	6·66	360·	...	88·5	0·89	0·87	0·87	0·72	5·89
120·	28·0?	28·5	1·30	1·45	1·28	1·30	6·39	400·	...	98·5	0·85	0·73	0·83	0·58	5·80
160·	...	38·0	1·29	1·43	1·27	1·28	6·38	440·	...	108·5	0·67	0·72	0·65	0·57	5·71
200·	...	48·0	1·25	1·21	1·23	1·06	6·25	480·	...	119·0	0·67	0·62	0·65	0·42	5·63
240·	...	57·5	1·15	1·15	1·13	1·00	6·17	520·	...	...	...	...	...	...	...

8th Aug., 1837. **WAVE XLVII.** Depth 5 inches.

Generating solid C. projected. Volume added = 445·1 inches.
Observers, α Russell, β Patrick, γ Hamil, δ Donaldson, Gen. Nimmo.

Statical level observed at $\left\{\begin{array}{l}\gamma = 0{\cdot}02 \\ \delta = 0{\cdot}15\end{array}\right\}$ Corrected depth = 5·10 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·0	0·0	1·90	2·05	1·88	1·90	...	240·	56·25	56·25	1·20	1·25	1·18	1·10	...
40·	9·0	9·0	1·80	2·03	1·78	1·88	...	280·	...	67·0	1·15	1·21	1·13	1·06	...
80·	18·5	19·0	1·70	1·85	1·68	1·70	...	320·	...	76·5	1·00	1·05	0·98	0·73	...
120·	27·75	28·0	1·70	1·80	1·68	1·65	...	360·	...	86·5	0·90	0·85	0·88	0·73	...
160·	39·0	...	...	...	...	...	...	400·	...	96·5	0·80	1·01	0·78	0·63	...
200·	46·75	47·0	1·45	1·45	1·43	1·30	...	440·	...	107·0	0·72	...	0·70	0·55	...

8th Aug., 1837. **WAVE XLVIII.** Depth 6 inches.

Generated by protrusion of solid C. Volume added = 547·5 inches.
Observers, α Russell, β Patrick, γ Hamil, δ Donaldson, Gen. Nimmo.

Statical level observed at $\left\{\begin{array}{l}\gamma = +0{\cdot}15\\ \delta = +0{\cdot}25\end{array}\right\}$ Corrected depth = 6·20 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	...	...	2·50	...	2·35	...	8·55	280·	54·0	...	1·00	...	0·85	...	7·05
40·	0·0	0·0	1·80	...	1·65	...	7·85	320·	63·5	...	0·90	...	0·75	...	6·95
80·	9·0	...	1·70	...	1·55	...	7·75	360·	73·0	...	0·85	...	0·70	...	6·90
120·	17·5	...	1·70	...	1·55	...	7·75	400·	82·5	...	0·80	...	0·65	...	6·85
160·	26·5	...	1·55	...	1·40	...	7·60	440·	91·5	...	0·70	...	0·55	...	6·75
200·	35·5	...	1·45	...	1·30	...	7·50	480·	101·0	...	0·70	...	0·55	...	6·75
240·	45·0	...	1·27	...	1·12	...	7·32	520·	110·0	...	0·67	...	0·52	...	6·72

8th Aug., 1837. **WAVE XLIX.** Depth 6 inches.

Generated by protrusion of solid C. Volume added = 547·5 inches.
Observers, α Russell, β Patrick, γ Hamil, δ Donaldson, Gen. Nimmo.

Statical level observed at $\left\{\begin{array}{l}\gamma = +0{\cdot}15\\ \delta = +0{\cdot}25\end{array}\right\}$ Corrected depth = 6·20 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	0·	...	1·55	...	1·40	...	7·60	500·	112·5	...	0·57	...	0·42	...	6·62
40·	0·	...	1·50	...	1·35	...	7·55	540·	122·0	...	0·57	...	0·42	...	6·62
80·	9·0	...	1·37	...	1·22	...	7·42	580·	131·5	...	0·50	...	0·35	...	6·55
120·	18·0	...	1·20	...	1·05	...	7·25	620·	141·0	...	0·50	...	0·35	...	6·55
160·	27·0	...	1·17	...	1·02	...	7·22	640·	151·5	...	0·50	...	0·35	...	6·55
200·	36·5	...	1·17	...	1·02	...	7·22	680·	161·5	...	0·47	...	0·32	...	6·52
240·	45·0	...	1·15	...	1·00	...	7·20	720·	171·0	...	0·47	...	0·32	...	6·52
280·	55·0	...	1·07	...	0·92	...	7·12	760·	181·0	...	0·45	...	0·30	...	6·50
320·	64·5	...	0·97	...	0·82	...	7·02	800·	190·5	...	0·42	...	0·27	...	6·47
360·	74·0	...	0·87	...	0·72	...	6·92	840·	200·0	...	0·42	...	0·27	...	6·47
400·	83·5	...	0·72	...	0·53	...	6·73	880·	210·0	...	0·40	...	0·25	...	6·45
440·	93·0	...	0·67	...	0·52	...	6·72	920·	220·0	...	...	...	...	...	...
480·	102·5	...	0·60	...	0·45	...	6·65	960·	230·0	...	...	...	...	...	...

8th Aug., 1837. **WAVE L.** Depth 6 inches.

Generated by protrusion of solid C. Volume added = 353·2 inches.
Observers, α Russell, β Patrick, γ Hamil, δ Donaldson, Gen. Nimmo.

Statical level observed at $\left\{\begin{array}{l}\gamma = +0{\cdot}20\\ \delta = +0{\cdot}30\end{array}\right\}$ Corrected depth = 6·25 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	...	...	1·40	...	1·20	...	7·45	480·	95·5	...	0·57	...	0·37	...	6·62
40·	...	...	1·10	...	0·90	...	7·15	520·	105·5	...	0·50	...	0·30	...	6·55
80·	0·0	...	1·07	...	0·87	...	7·12	560·	115·0	...	0·50	...	0·30	...	6·55
120·	9·5	...	0·97	...	0·77	...	7·02	600·	124·5	...	0·50	...	0·30	...	6·55
160·	18·5	...	0·87	...	0·67	...	6·92	640·	134·5	...	0·47	...	0·27	...	6·52
200·	28·5	...	0·82	...	0·62	...	6·87	680·	144·5	...	0·40	...	0·20	...	6·45
240·	37·5	...	0·82	...	0·62	...	6·87	720·	154·5	...	0·40	...	0·20	...	6·45
280·	47·5	...	0·80	...	0·60	...	6·85	760·	164·0	...	0·37	...	0·10	...	6·35
320·	56·5	...	0·72	...	0·52	...	6·77	800·	174·0	...	0·37	...	0·10	...	6·35
360·	66·5	...	0·70	...	0·50	...	6·75	840·	184·0	...	0·35	...	0·15	...	6·40
400·	76·5	...	0·67	...	0·47	...	6·72	880·	194·0	...	0·35	...	0·15	...	6·40
440·	86·0	...	0·60	...	0·40	...	6·65	920·	...	...	...	...	...	...	...

8th Aug., 1837. WAVE LI. Depth, 7 inches.

Generated by protrusion of solid C. Volume added = 309·12 inches.
Observers, α Russell, β Patrick, γ Hamil, δ Donaldson, Gen. Nimmo.
Statical level observed at $\left\{\begin{matrix}\gamma = -0{\cdot}02\\ \delta = +0{\cdot}08\end{matrix}\right\}$ Corrected depth = 7·04 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ′ in.	δ′ in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ′ in.	δ′ in.	in.
0·	...	...	0·9	...	0·92	...	7·96	320·	53·5	...	0·65	...	0·67	...	7·71
40·	...	...	0·9	...	0·92	...	7·96	360·	63·0	...	0·62	...	0·64	...	7·68
80·	0·0	...	0·87	...	0·89	...	7·93	400·	72·5	...	0·62	...	0·64	...	7·68
120·	9·0	...	0·80	...	0·82	...	7·86	440·	81·5	...	0·60	...	0·62	...	7·66
160·	18·5	...	0·80	...	0·82	...	7·86	480·	...	...	0·60	...	0·62	...	7·66
200·	27·5	...	0·77	...	0·79	...	7·82	520·	...	...	0·50	...	0·52	...	7·56
240·	36·0	...	0·77	...	0·79	...	7·82	560·	...	...	...	...	...	...	...
280·	45·0	...	0·70	...	0·72	...	7·76	600·	...	...	...	...	...	...	...

8th Aug., 1837. WAVE LII. Depth, 7 inches.

Generated by protrusion of solid C. Volume added = 309·12 inches.
Observers, α Russell, β Patrick, γ Hamil, δ Donaldson, Gen. Nimmo.
Statical level observed at $\left\{\begin{matrix}\gamma = -0{\cdot}02\\ \delta = +0{\cdot}08\end{matrix}\right\}$ Corrected depth = 7·04 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ′ in.	δ′ in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ′ in.	δ′ in.	in.
0·	...	...	1·0	...	1·02	...	8·06	200·	35·25	...	0·85	...	0·87	...	7·91
40·	0·	0·	0·97	...	0·99	...	8·03	240·	44·5	...	0·75	...	0·77	...	7·81
80·	8·5	...	0·95	...	0·97	...	8·01	280·	53·0	...	0·67	...	0·69	...	7·71
120·	17·5	...	0·95	...	0·97	...	8·01	320·	62·5	...	0·70	...	0·72	...	7·76
160·	26·5	...	0·90	...	0·92	...	7·96	360.	71·5	...	0·60	...	0·62	...	7·66

8th Aug., 1837. WAVE LIII. Depth, 7 inches.

Generated by protrusion of solid C. Volume added = 309·12 inches.
Observers, α Russell, β Patrick, γ Hamil, δ Donaldson, Gen. Nimmo.
Statical level observed at $\left\{\begin{matrix}\gamma = -0{\cdot}02\\ \delta = +0{\cdot}08\end{matrix}\right\}$ Corrected depth = 7·04 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ′ in.	δ′ in.	in.	feet.	α sec.	βsec.	γ in.	δ in.	γ′ in.	δ′ in.	in.
0·	0·0	0·0	0·87	...	0·89	...	7·93	400·	39·5	...	0·62	...	0·64	...	7·68
40·	9·0	...	0·77	...	0·79	...	7·83	440·	49·0?	...	0·52	...	0·54	...	7·58
80·	18·0	...	0·72	...	0·74	...	7·78	480·	58·5	...	0·47	...	0·49	...	7·53
120·	27·0	...	0·72	...	0·74	...	7·78	520·	68·0	...	0·40	...	0·42	...	7·46
160·	36·0	...	0·72	...	0·74	...	7·78	560·	77·0	...	0·40	...	0·42	...	7·46
...	...	...	...	...	...	...	...	600·	86·0	...	0·37	...	0·39	...	7·43
280·	*12·0	...	0·67	...	0·69	...	7·73	640·	95·0	...	0·37	...	0·39	...	7·43
320·	21·0	...	0·65	...	0·67	...	7·71	680·	104·0	...	0·30	...	0·32	...	7·36
360·	30·0	...	0·62	...	0·64	...	7·68	720·	113·5	...	0·30	...	0·32	..	7·36

8th Aug., 1837. **WAVE LIV.*** Depth, 7 inches.

Generated by protrusion of solid C. Volume added = 309·1 inches.
Observers, α Russell, β Patrick, γ Hamil, δ Donaldson, Gen. Nimmo.
Statical level observed at $\left\{\begin{matrix}\gamma = -\ 0{\cdot}02 \\ \delta = +\ 0{\cdot}08\end{matrix}\right\}$ Corrected depth = 7·04 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	β in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	...	...	0·90	...	0·92	...	7·96	320·	54·0	...	0·60	...	0·62	...	7·66
40·	...	...	0·87	...	0·89	...	7·93	360·	63·0	...	0·57	...	0·59	...	7·63
80·	0·0	...	0·77	...	0·79	...	7·83	400·	72·0	...	0·55	...	0·57	...	7·61
120·	9·0	...	0·67	...	0·69	...	7·73	440·	81·0	...	0·50	...	0·52	...	7·56
160·	18·0	...	0·67	...	0·69	...	7·73	480·	90·0	...	0·47	...	0·49	...	7·53
200·	27·0	...	0·70	...	0·72	...	7·76	520·	100·0	...	0·47	...	0·49	...	7·53
240·	36·0	...	0·62	...	0·64	...	7·68	560·	109·0	...	0·50	...	0·52	...	7·56
280·	45·0	...	0·60	...	0·62	...	7·66	600·	119·0	...	0·45	...	0·47	...	7·51

* Very irregularly observed.

8th Aug., 1837. **WAVE LV.** Depth, 7 inches.

Generated by protrusion of solid C. Volume added = 309·1 inches.
Observers, α Russell, β Patrick, γ Hamil, δ Donaldson, Gen. Nimmo.
Statical level observed at $\left\{\begin{matrix}\gamma = -\ 0{\cdot}02 \\ \delta = +\ 0{\cdot}08\end{matrix}\right\}$ Corrected depth = 7·04 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	...	...	0·90	...	0·92	...	7·96	720·	142·5	...	0·37	...	0·39	...	7·43
40·	...	...	0·90	...	0·92	...	7·96	760·	152·0	...	0·37	...	0·39	...	7·43
80·	0·0	...	0·87	...	0·89	...	7·93	800·	161·0	...	0·32	...	0·34	...	7·38
120·	8·5	...	0·82	...	0·84	...	7·88	840·	170·0	...	0·30	...	0·32	...	7·36
160·	17·5	...	0·80	...	0·82	...	7·86	880·	179·0	...	0·30	...	0·32	...	7·36
200·	26·5	...	0·75	...	0·77	...	7·81	920·	188·0	...	0·30	...	0·32	...	7·36
240·	35·5	...	0·72	...	0·74	...	7·78	960·	197·5	...	0·27	...	0·29	...	7·33
280·	44·0	...	0·70	...	0·72	...	7·76	1000·	206·5	...	0·27	...	0·29	...	7·33
320·	53·0	...	0·67	...	0·69	...	7·73	1040·	216·0	...	0·27	...	0·29	...	7·33
360·	62·0	...	0·60	...	0·62	...	7·66	1080·	225·0	...	0·22	...	0·24	...	7·28
400·	71·0	...	0·57	...	0·59	...	7·53	1120·	234·0	...	0·20	...	0·22	...	7·26
440·	80·0	...	0·52	...	0·54	...	7·58	1160·	243·0	...	0·20	...	0·22	...	7·26
480·	89·0	...	0·50	...	0·52	...	7·56	1200·	...	...	...	...	...	...	...
520·	...	...	0·50	...	0·52	...	7·56	1240·	...	...	...	...	...	...	...
560·	106·5	...	0·47	...	0·49	...	7·53	1280·	...	...	...	...	...	...	...
600·	115·5	...	0·47	...	0·49	...	7·53	1320·	...	...	...	...	...	...	...
640·	125·0	...	0·42	...	0·44	...	7·48	1360·	...	...	...	...	...	...	...
680·	134·0	...	0·40	...	0·42	...	7·46	1400·	...	...	...	...	...	...	...

9th Aug., 1837. WAVE LVI. Triangular channel (H).

Generated by protrusion of solid parallelopipedon, C.
Times observed directly at Station γ, double transits.
Time, β Patrick, Index, γ Hamil, Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\gamma = -0·10\\ \delta = +0·02\end{array}\right\}$ Corrected depth = 4·012 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	...	0·0	0·30	...	0·40	...	...	75·5	...	34·5	0·00	...	0·10	...	...
35·5	...	14·5	0·10	...	0·20	...	...	115·5	...	49·5	0·02	...	0·08	...	...

9th Aug., 1837. WAVE LVII. Triangular channel (H).

Generated by protrusion of solid parallelopipedon, C.
Times observed directly at Station γ, double transits.
Time, β Patrick, Index, γ Hamil, Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\gamma = -0·10\\ \delta = +0·02\end{array}\right\}$ Depth = 4·012 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	...	0·0	0·30	...	0·40	...	...	75·5	...	34·5	0·07	...	0·17	...	...
35·5	...	14·5	0·20	...	0·30	...	...	115·5	...	49·5	0·00	...	0·10	...	...

9th Aug., 1837. WAVE LVIII. Triangular channel (H).

Generated by protrusion of solid parallelopipedon, C.
Times observed directly at Station γ, double transits.
Time, β Patrick, Index, γ Hamil, Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\gamma = -0·10\\ \delta = +0·02\end{array}\right\}$ Corrected depth = 4·012 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	...	0·00	0·80	...	0·90	...	4·91	115·5	...	46·5	0·07	...	0·17	...	4·18
35·5	...	13·5	0·40	...	0·50	...	4·51	155·5	...	64·5	0·02	...	0·12	...	4·13
75·5	...	30·0	0·17	...	0·27	...	4·28	195·5	...	...	...	...	...	...	...

9th Aug., 1837. WAVE LIX. Triangular channel (H).

Generated by protrusion of solid parallelopipedon, C.
Times observed directly at Station γ, double transits.
Time, β Patrick, Index, γ Hamil, Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\gamma = -0·10\\ \delta = +0·02\end{array}\right\}$ Corrected depth = 4·012 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	...	0·0	1·10	...	1·20	...	5·21	75·5	...	29·0	0·17	...	0·27	...	4·28
35·5	...	14·0	0·40	...	0·50	...	4·51	115·5	...	46·5	0·07	...	0·17	...	4·18

9th Aug., 1837. WAVE LX. Triangular channel (H).

Generated by protrusion of solid parallelopipedon, C.
Times observed directly at Station γ, double transits.
Time, β Patrick, Index, γ Hamil, Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\gamma = -\ 0{\cdot}10 \\ \delta = +\ 0{\cdot}02\end{array}\right\}$ Corrected depth = 4·012 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	...	0·	1·05	...	1·15	...	5·16	75·5	...	30·0	0·10	...	0·20	...	4·21
35·5	...	13·5	0·35	...	0·45	...	4·46	115·5	...	47·5	...	...	...	...	...

9th Aug., 1837. WAVE LXI. Triangular channel (H).

Generated by protrusion of solid parallelopipedon, C.
Times observed directly at Station γ, double transits.
Time, β Patrick, Index, γ Hamil, Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\gamma = -\ 0{\cdot}10 \\ \delta = +\ 0{\cdot}02\end{array}\right\}$ Corrected depth = 4·012 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	...	0·0	1·10	...	1·20	...	5·21	75·5	...	29·5	0·10	...	0·20	...	4·21
35·5	...	13·5	0·30	...	1·40	...	5·41	115·5	...	47·0	0·00	...	0·10	...	4·11

9th Aug., 1837. WAVE LXII. Triangular channel (H).

Generated by protrusion of solid parallelopipedon, C.
Times observed directly at Station γ, double transits.
Time, β Patrick, Index, γ Hamil, Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\gamma = +\ 0{\cdot}02 \\ \delta = +\ 0{\cdot}15\end{array}\right\}$ Corrected depth = 5·11 inches.

A	B		C		D		E	A	B		C		D		E
feet,	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	...	0·0	1·10	...	1·98	...	7·09	155·5	...	56·0	0·22	...	0·20	...	5·31
35·5	...	12·0	0·70	...	0·68	...	5·79	195·5	...	71·0	0·20	...	0·18	...	5·29
75·5	...	26·0	0·50	...	0·48	...	5·59	235·5	...	87·0	0·17	...	0·15	...	5·26
115·5	...	41·0	0·30	...	0·28	...	5·39	275·5	...	...	...	...	...	...	...

9th Aug., 1837. WAVE LXIII. Triangular channel (H).

Generated by protrusion of solid parallelopipedon, C.
Times observed directly at Station γ, double transits.
Time, β Patrick, Index, γ Hamil, Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\gamma = +\ 0{\cdot}02 \\ \delta = +\ 0{\cdot}15\end{array}\right\}$ Corrected depth = 5·11 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·0	...	0·0	1·10	...	1·08	...	6·19	115·5	...	41·5	0·30	...	0·28	...	5·39
35·5	...	12·5	0·70	...	0·68	...	5·79	155·5	...	56·0	0·22	...	0·20	...	5·31
75·5	...	26·5	0·45	...	0·43	...	5·54	195·5	...	...	0·17	...	0·15	...	5·26

9th Aug., 1837. WAVE LXIV. Triangular channel (H).

Generated by protrusion of solid parallelopipedon, C.
Times observed directly at Station γ, double transits.
Time, β Patrick, Index, γ Hamil, Transit, Russell.

Statical level observed at $\left\{ \begin{array}{l} \gamma = +\ 0{\cdot}02 \\ \delta = +\ 0{\cdot}15 \end{array} \right\}$ Corrected depth = 5·11 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·0	...	0·0	1·10	...	1·08	...	6·19	115·5	...	40·5	0·30	...	0·28	...	5·39
35·5	...	12·0	0·70	...	0·68	...	5·79	155·5	...	55·5	0·20	...	0·18	...	5·29
75·5	...	26·0	0·40	...	0·38	...	5·49	195·5	...	71·0	...	...	...	...	...

9th Aug., 1837. WAVE LXV. Triangular channel (H).

Generated by protrusion of solid parallelopipedon, C.
Times observed directly at Station γ, double transits.
Time, β Patrick, Index, γ Hamil, Transit, Russell.

Statical level observed at $\left\{ \begin{array}{l} \gamma = +\ 0{\cdot}02 \\ \delta = +\ 0{\cdot}15 \end{array} \right\}$ Corrected depth = 5·11 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·0	...	0·	1·20	...	1·18	...	6·29	115·5	...	40·5	0·27	...	0·25	...	5·36
35·5	...	12·0	0·60	...	0·58	...	5·69	155·5	...	55·5	0·20	...	0·18	...	5·29
75·5	...	26·0	0·35	...	0·33	...	5·44	195·5	...	71·0	...	...	...	...	...

9th Aug., 1837. WAVE LXVI. Triangular channel (H).

Generated by protrusion of solid parallelopipedon, C.
Times observed directly at Station γ, double transits.
Time, β Patrick, Index, γ Hamil, Transit, Russell.

Statical level observed at $\left\{ \begin{array}{l} \gamma = +\ 0{\cdot}00 \\ \delta = +\ 0{\cdot}05 \end{array} \right\}$ Corrected depth = 6·04 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	...	0·	0·80	...	0·80	...	6·84	155·5	...	51·5	0·20	...	0·20	...	6·24
35·5	...	11·0	0·65	...	0·65	...	6·69	195·5	...	65·0	0·12	...	0·12	...	6·16
75·5	...	23·5	0·37	...	0·37	...	6·41	235·5	...	79·5	0·10	...	0·10	...	6·14
115·5	...	37·5	0·32	...	0·32	...	6·36	275·5	...	...	...	...	...	...	...

9th Aug., 1837. WAVE LXVII. Triangular channel (H).

Generated by protrusion of solid parallelopipedon, C.
Times observed directly at Station γ, double transits.
Time, β Patrick, Index, γ Hamil, Transit, Russell.

Statical level observed at $\left\{ \begin{array}{l} \gamma = +\ 0{\cdot}00 \\ \delta = +\ 0{\cdot}05 \end{array} \right\}$ Corrected depth = 6·04 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·0	...	0·0	0·85	...	0·85	...	6·89	115·5	...	38·0	0·32	...	0·32	...	6·36
35·5	...	11·5	0·67	...	0·67	...	6·71	155·5	...	52·0	0·19	...	0·19	...	6·23
75·5	...	24·5	0·47	...	0·47	...	6·51	195·5	...	66·0	0·15	...	0·15	...	6·19

9th Aug., 1837. WAVE LXVIII. Triangular channel (H).

Generated by protrusion of solid parallelopipedon, C.
Times observed directly at Station γ, double transits.
Time, β Patrick, Index, γ Hamil, Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\gamma = +\ 0{\cdot}00\\ \delta = +\ 0{\cdot}05\end{array}\right\}$ Corrected depth = 6·04 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·0	...	0·0	1·10	...	1·10	...	7·14	115·5	...	37·5	0·27	...	0·27	...	6·31
35·5	...	11·0	0·77	...	0·77	...	6·81	155·5	...	51·5	0·20	...	0·20	...	6·24
75·5	...	24·0	0·37	...	0·37	...	6·41	195·5	...	65·0	0·17	...	0·17	...	6·21

9th Aug., 1837. WAVE LXIX. Triangular channel (H).

Generated by protrusion of solid parallelopipedon, C.
Times observed directly at Station γ, double transits.
Time, β Patrick, Index, γ Hamil, Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\gamma = -\ 0{\cdot}02\\ \delta = +\ 0{\cdot}05\end{array}\right\}$ Statical depth = 7·04 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·0	...	0·0	...	...	...	...	...	75·5	...	25·0	0·25	...	0·27	...	7·31
35·5	...	12·0	0·40	...	0·42	...	7·46	115·5	...	...	...	...	...	...	...

9th Aug., 1837. WAVE LXX. Triangular channel (H).

Generated by protrusion of solid parallelopipedon, C.
Times observed directly at Station γ, double transits.
Time, β Patrick, Index, γ Hamil, Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\gamma = -\ 0{\cdot}02\\ \delta = +\ 0{\cdot}05\end{array}\right\}$ Corrected depth = 7·04 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·0	...	0·0	...	...	...	...	...	155·5	...	50·5	0·20	...	0·22	...	7·26
35·5	...	11·5	...	...	...	...	...	195·5	...	63·5	0·07	...	0·09	...	7·13
75·5	...	24·5	0·50	...	0·52	...	7·56	235·5	...	76·0	0·05	...	0·07	...	7·10
115·5	...	37·0	0·30	...	0·32	...	7·36	275·5	...	90·0	0·02	...	0·04	...	7·08

9th Aug., 1837. WAVE LXXI. Triangular channel (H).

Generated by protrusion of solid parallelopipedon, C.
Times observed directly at Station γ, double transits.
Time, β Patrick, Index, γ Hamil, Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\gamma = -\ 0{\cdot}02\\ \delta = +\ 0{\cdot}05\end{array}\right\}$ Corrected depth = 7·04 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·0?	...	0·0	...	...	...	...	...	155·5	...	52·0	0·15	...	0·17	...	7·21
35·5?	...	14·5?	1·2?	...	1·22?	...	8·26	195·5	...	65·5	0·10	...	0·12	...	7·16
75·5	...	26·5	0·5	...	0·52	...	7·56	235·5	...	78·5	0·07	...	0·09	...	7·13
115·5	...	39·0	0·2	...	0·22	...	7·26	275·5	...	91·0	0·05	...	0·07	...	7·11

9th Aug., 1837. **WAVE LXXII.** Triangular Channel (H).

Generated by protrusion of solid parallelopipedon C.
Times observed directly at Station γ, double transits.
Time, β Patrick, Index, γ Hamil, Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\gamma = -0{\cdot}10\\ \delta = +0{\cdot}05\end{array}\right\}$ Corrected depth = 7·04 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ'in.	δ'in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ'in.	δ'in.	in.
0·	...	0·0	...	...	...	...	...	155·5	...	50·5	0·10	...	0·12	...	7·16
35·5	...	11·5	...	...	...	...	...	195·5	...	62·5	0·07	...	0·09	...	7·13
75·5	...	22·5	0·25	...	0·27	...	7·31	235·5	...	76·5	0·05	...	0·07	...	7·11
115·5	...	37·0	0·17	...	0·19	...	7·23	275·5	...	...	...	...	...	...	

9th Aug., 1837. **WAVE LXXIII.** Triangular Channel (H).

Generated by protrusion of solid parallelopipedon C.
Times observed directly at Station γ, double transits.
Time, β Patrick, Index, γ Hamil, Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\gamma = -0{\cdot}10\\ \delta = +0{\cdot}05\end{array}\right\}$ Corrected depth = 7·04 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ'in.	δ'in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ'in.	δ'in.	in.
0·0	...	0·0	...	...	...	...	...	155·5	...	50·5	0·17	...	0·19	...	7·23
35·5	...	12·5	0·60	...	0·62	...	7·66	195·5	...	64·0	0·10	...	0·12	...	7·16
75·5	...	24·0	0·45	...	0·47	...	7·51	235·5	...	76·5	0·05	...	0·07	...	7·11
115·5	...	37·5	0·27	...	0·29	...	7·33	275·5	...	...	...	...	...	...	...

9th Aug., 1837. **WAVE LXXIV.** Triangular Channel (H).

Generated by protrusion of solid parallelopipedon C.
Times observed directly at Station γ, double transits.
Time, β Patrick, Index, γ Hamil, Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\gamma = -0{\cdot}10\\ \delta = +0{\cdot}05\end{array}\right\}$ Corrected depth = 7·04 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ'in.	δ'in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ'in.	δ'in.	in.
0·0	...	0·0	...	...	...	...	...	155·5	...	48·0	0·17	...	0·19	...	7·23
35·5	...	11·5	0·65	...	0·62	...	7·66	195·5	...	61·5	0·10	...	0·12	...	7·16
75·5	...	23·0	0·50	...	0·52	...	7·56	235·5	...	74·5	0·02	...	0·04	...	7·08
115·5	...	35·5	0·30	...	0·32	...	7·36	275·5	...	87·5	0·00	...	0·02	...	7·06

9th Aug., 1837. WAVE LXXV. Triangular Channel (H).

Generated by protrusion of solid parallelopipedon C.
Times observed directly at Station γ, double transits.
Time, β Patrick, Index, γ Hamil, Transit, Russell.

Statical level observed at $\left\{\begin{array}{l}\gamma = -0{\cdot}10 \\ \delta = +0{\cdot}05\end{array}\right\}$ Corrected depth = 7·04 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ'in.	δ'in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ'in.	δ'in.	in.
0·0	...	0·0	...	...	...	...	...	155·5	...	49·0	0·15	...	0·17	...	7·21
35·5	...	11·5	0·60	...	0·62	...	7·66	195·5	...	62·0	0·07	...	0·09	...	7·13
75·5	...	24·0	0·45	...	0·47	...	7·51	235·5	...	75·5	0·05	...	0·07	...	7·11
115·5	...	36·5	0·30	...	0·32	...	7·36	275·5	...	88·5	0·00	...	0·00	...	7·04

Remark.—In this series of experiments it was observed that the wave was long and low on the deep side, and comparatively sharp and short on the shallow side, so that the outline of the wave was formed of convergent lines. The wave did not always break on the shallow side, but broke on that side much earlier than on the other side.

11th Aug., 1837. WAVE LXXVI. Triangular Channel (K).

Generated by protrusion of solid parallelopipedon C.
Times observed directly at Stations γ and δ, single transits.
Time, α Russell, Index, γ Hamil, Index, δ Donaldson.

Statical level observed at $\left\{\begin{array}{l}\gamma = +0{\cdot}05 \\ \delta = +0{\cdot}10\end{array}\right\}$ Corrected depth = 4·04 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ'in.	δ'in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ'in.	δ'in.	in.
0·0	0·0	...	1·0	...	0·95	...	4·99	55·7	21·5	...	...	0·30	...	0·20	4·24
14·62	5·0	...	...	0·7	...	0·60	4·64	75·7	29·5	...	0·20	...	0·15	...	4·19
35·7	13·0	...	0·6	...	0·55	...	4·39	95·7	...	...	...	...	...	...	...

11th Aug., 1837. WAVE LXXVII. Triangular Channel (K).

Generated by protrusion of solid parallelopipedon C.
Times observed directly at Stations γ and δ, single transits.
Time, α Russell, Index, γ Hamil, Index, δ Donaldson.

Statical level observed at $\left\{\begin{array}{l}\gamma = +0{\cdot}05 \\ \delta = +0{\cdot}10\end{array}\right\}$ Corrected depth = 4·04 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ'in.	δ'in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ'in.	δ'in.	in.
0·0	0·0	...	1·+	...	1·+	...	...	55·7	21·5	...	...	0·30	...	0·2	4·24
14·6	5·25	...	...	0·65	...	0·55	4·59	75·7	...	...	...	...	...	...	...
35·7	13·0	...	0·43	...	0·38	...	4·42	95·7	...	...	...	...	...	...	...

11th Aug., 1837. **WAVE LXXVIII.** Triangular Channel (K).

Generated by protrusion of solid parallelopipedon C.
Times observed directly at Stations γ and δ, single transits.
Time, α Russell, Index, γ Hamil, Index, δ Donaldson.

Statical level observed at $\left\{\begin{matrix} \gamma = +\,0{\cdot}05 \\ \delta = +\,0{\cdot}10 \end{matrix}\right\}$ Corrected depth = 4·04 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ'in.	δ'in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ'in.	δ'in.	in.
0·0	0·0	...	2·0	...	1·95	...	5·99	55·7	20·5	...	...	0·32	...	0·22	4·26
14·6	5·0	...	...	0·70	...	0·60	4·64	75·7	29·5	...	0·25	...	0·20	...	4·24
35·7	12·5	...	0·50	...	0·45	...	4·49	95·7	38·0	...	...	0·20	...	0·10	4·14

11th Aug., 1837. **WAVE LXXIX.** Triangular Channel (K).

Generated by protrusion of solid parallelopipedon C.
Times observed directly at Stations γ and δ, single transits.
Time, α Russell, Index, γ Hamil, Index, δ Donaldson.

Statical level observed at $\left\{\begin{matrix} \gamma = +\,0{\cdot}05 \\ \delta = +\,0{\cdot}10 \end{matrix}\right\}$ Corrected depth = 4·04 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ'in.	δ'in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ'in	δ'in.	in.
0·0	0·0	...	2·20	...	2·15	...	6·19	75·7	29·5	...	0·20	...	0·15	...	4·19
14·6	5·0	...	...	0·70	...	0·60	4·64	95·7	37·7	...	...	0·19	...	0·09	4·13
35·7	13·0	...	0·45	...	0·40	...	4·44	115·7	49·0	...	0·10	...	0·05	...	4·09
55·7	21·2	...	...	0·32	...	0·22	4·26	135·7	...	...	...	...	...	...	...

Remarks.—The times at γ and δ were differently observed, and should be separated. The wave was long and low on the deep side, and tapered to a point on the other side. It broke during the whole period of observation continually on the shallow edge, leaving a portion behind, from which subordinate waves were formed.

11th Aug., 1837. **WAVE LXXX.** Trapezoidal Channel (L).

Statical level observed at $\left\{\begin{matrix} \gamma = -\,0{\cdot}05 \\ \delta = \,0{\cdot}00 \end{matrix}\right\}$ Corrected depth = 5·00 inches.

Wave observed by sight.	Wave observed in glass index.
2·5 inches high.	1·5 inches high.
0·75	0·75 ... ...
0·25	0·25 ... ...

Observations of this kind having been repeated, it was found that high waves, exceeding about half the mean depth, were indicated higher on the side by direct sight than in the index, up to about the limit when the excess became nearly one half of the whole height.

11th Aug., 1837. WAVE LXXXI. Trapezoidal Channel (L).

Generated by protrusion of solid parallelopipedon C.
Times observed directly at Stations γ and δ, single transits.
Time, α Russell, Index, γ Hamil, Index, δ Donaldson.

Statical level observed at $\left\{\begin{matrix}\gamma = -\ 0{\cdot}05 \\ \delta = \cdot\ \ 0{\cdot}00\end{matrix}\right\}$ Corrected depth = 5·00 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	...	0·0	2·0	...	2·05	...	7·05	55·7	...	17·5	...	0·50	...	0·50	5·50
14·6	...	4·5	...	0·80	...	0·80	5·80	75·7	...	25·0	0·25	...	0·30	...	5·30
35·7	...	11·0	0·70	...	0·75	...	5·75	95·7	...	...	...	...	...	...	...

11th Aug., 1837. WAVE LXXXII. Trapezoidal Channel (L).

Generated by protrusion of solid parallelopipedon C.
Times observed directly at Stations γ and δ, single transits.
Time, α Russell, Index, γ Hamil, Index, δ Donaldson.

Statical level observed at $\left\{\begin{matrix}\gamma = +\ 0{\cdot}05 \\ \delta = +\ 0{\cdot}10\end{matrix}\right\}$ Corrected depth = 5·00 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	γ sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·	...	0·0	2·0	...	2·05	...	7·05	55·7	...	17·75	...	0·6	...	0·6	5·60
14·6	...	4·5	...	0·9	...	0·9	5·90	75·7	...	24·5	0·35	...	0·40	...	5·40
35·7	...	11·0	0·75	...	0·80	...	5·80	95·7	...	31·25	...	0·25	...	0·25	5·25

11th Aug., 1837. WAVE LXXXIII. Trapezoidal Channel (L).

Generated by protrusion of solid parallelopipedon C.
Times observed directly at Stations γ and δ, single transits.
Time, α Russell, Index, γ Hamil, Index, δ Donaldson.

Statical level observed at $\left\{\begin{matrix}\gamma = +\ 0{\cdot}05 \\ \delta = +\ 0{\cdot}10\end{matrix}\right\}$ Corrected depth = 5·00 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·0	...	0·0	2·5	...	2·55	...	7·55	55·7	...	16·75	...	0·55	...	0·55	5·55
14·6	...	4·0	...	0·8	...	0·80	5·80	75·7	...	24·0	...	...	...	...	...
35·7	...	10·5	0·7	...	0·75	...	5·75	95·7	...	30·5	...	...	...	...	...

11th Aug., 1837. WAVE LXXXIV. Trapezoidal Channel (L).

Generated by protrusion of solid parallelopipedon C.
Times observed directly at Stations γ and δ, single transits.
Time, α Russell, Index, γ Hamil, Index, δ Donaldson.

Statical level observed at $\left\{\begin{matrix}\gamma = +\ 0{\cdot}05 \\ \delta = +\ 0{\cdot}10\end{matrix}\right\}$ Corrected depth = 5·00 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·0	...	0·0	2·0	...	2·05	...	7·05	55·7	...	17·5	...	0·55	...	0·55	5·55
14·6	...	4·0	...	0·80	...	0·80	5·80	75·7	...	24·5	0·30	...	0·35	...	5·35
35·7	...	10·5	0·65	...	0·70	...	5·70	95·7	...	...	...	...	...	...	...

11th Aug., 1837. WAVE LXXXV. Trapezoidal Channel (L).

Generated by protrusion of solid parallelopipedon C.
Times observed directly at Stations γ and δ, single transits.
Time, α Russell, Index, γ Hamil, Index, δ Donaldson.

Statical level observed at $\left\{ \begin{array}{l} \gamma = +\ 0{\cdot}05 \\ \delta = +\ 0{\cdot}10 \end{array} \right\}$ Corrected depth = 5·00 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·0	...	0·0	2·50	...	2·55	...	7·55	75·7	...	24·5	0·30	...	0·35	...	5·35
14·6	...	4·0	...	0·80	...	0·80	5·80	95·7	...	29·5	...	0·22	...	0·22	5·22
35·7	...	10·5	0·70	...	0·75	...	5·75	115·7	...	37·0	0·10	...	0·15	...	5·15
55·7	...	17·0	...	0·52	...	0·52	5·52	135·7	...	...	...	...	...	...	...

11th Aug., 1837. WAVE LXXXVI. Trapezoidal Channel (L).

Generated by protrusion of solid parallelopipedon C.
Times observed directly at Stations γ and δ, single transits.
Time, α Russell, Index, γ Hamil, Index, δ Donaldson.

Statical level observed at $\left\{ \begin{array}{l} \gamma = +\ 0{\cdot}05 \\ \delta = +\ 0{\cdot}10 \end{array} \right\}$ Corrected depth = 5·00 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·0	...	0·0	2·+	...	2·+	...	7·00	55·7	...	17·0	...	0·47	...	0·47	5·47
14·6	...	4·0	...	0·90	...	0·90	5·90	75·7	...	25·5	...	...	...	...	...
35·7	...	10·5	...	...	...	...	...	95·7	...	37·5	...	0·25	...	0·25	5·25

11th Aug., 1837. WAVE LXXXVII. Trapezoidal Channel (L).

Generated by protrusion of solid parallelopipedon C.
Times observed directly at Stations γ and δ, single transits.
Time, α Russell, Index, γ Hamil, Index, δ Donaldson.

Statical level observed at $\left\{ \begin{array}{l} \gamma = +\ 0{\cdot}05 \\ \delta = +\ 0{\cdot}10 \end{array} \right\}$ Corrected depth = 5·00 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·0	...	0·0	...	...	...	...	...	55·7	...	17·0	...	0·52	...	0·52	5·52
14·6	...	4·5	...	0·85	...	0·85	5·85	75·7	...	26·0	...	...	...	...	...
35·7	...	11·0	...	...	...	...	...	95·7	...	38·0	...	0·25	...	0·25	5·25

11th Aug., 1837. WAVE LXXXVIII. Trapezoidal Channel (L).

Generated by protrusion of solid parallelopipedon C.
Times observed directly at Stations γ and δ, single transits.
Time, α Russell, Index, γ Hamil, Index, δ Donaldson.

Statical level observed at $\left\{ \begin{array}{l} \gamma = +\ 0{\cdot}05 \\ \delta = +\ 0{\cdot}10 \end{array} \right\}$ Corrected depth = 5·00 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·0	...	0·0	...	...	...	...	...	55·7	...	17·0	...	0·52	...	0·52	...
14·6	...	4·25	...	0·35	...	0·85	...	75·7	...	26·0	...	...	...	...	...
35·7	...	10·75	...	...	...	...	...	95·7	...	37·5	...	0·25	...	0·25	...

11th Aug., 1837. **WAVE LXXXIX*.** Trapezoidal Channel (L).

(1.) Height of the wave.	On the deep side	2·0	0·75	0·25
	On the shallow side ...	2·+	1·2	0·40
(2.) Height of the wave.	On the deep side	1·2	0·75	0·25
	On the shallow side ...	2·0	1·2	0·40
(3.) Height of the wave.	On the deep side	1·5	0·5	...
	On the shallow side ...	2·5	1·0	...
(4.) Height of the wave.	On the deep side	2·0	0·75	0·25
	On the shallow side ...	2·5	1·0	0·50

* In the whole of this series the wave broke on the shallow side immediately, and continued to do so, being dissipated very soon.

11th Aug., 1837. **WAVE XC.** Trapezoidal Channel (M).

Generated by addition of solid parallelopipedon C.
Times observed directly at γ and δ, single transits.
Time, α Russell, Index, γ Hamil, Index, δ Donaldson.

Statical level observed at $\left\{\begin{array}{l}\gamma = -0·07\\ \delta = +0·05\end{array}\right\}$ Corrected depth = 6·01 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·0	...	0·0	1·5	...	1·57	...	7·58	75·7	...	20·5	...	...	...	...	...
14·6	...	4·0	...	...	...	...	...	115·7	...	32·5	0·25	...	0·12	...	6·13
35·7	...	9·0	...	...	...	...	...	135·7	...	...	...	...	...	...	...

11th Aug., 1837. **WAVE XCI.** Trapezoidal Channel (M).

Generated by addition of solid parallelopipedon C.
Times observed directly at γ and δ, single transits.
Time, α Russell, Index, γ Hamil, Index, δ Donaldson.

Statical level observed at $\left\{\begin{array}{l}\gamma = -0·07\\ \delta = +0·05\end{array}\right\}$ Corrected depth = 6·01 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·0	...	0·0	...	...	...	...	...	75·7	...	21·0	...	0·5	...	0·45	6·58
14·6	...	4·0	...	1·5	...	1·45	7·46	115·7	...	33·5	0·2	...	0·27	...	6·40
35·7	...	9·5	0·7	...	0·77	...	6·78	135·7	...	...	...	...	...	...	...

11th Aug., 1837. **WAVE XCII.** Trapezoidal Channel (M).

Generated by addition of solid parallelopipedon C.
Times observed directly at γ and δ, single transits.
Time, α Russell, Index, γ Hamil, δ Index, Donaldson.

Statical level observed at $\left\{\begin{array}{l}\gamma = -0·07\\ \delta = -0·05\end{array}\right\}$ Corrected depth = 6·01 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·0	...	0·0	...	...	...	...	...	75·7	...	20·5	...	0·5	...	0·45	6·46
14·6	...	4·0	...	1·5	...	1·45	7·46	115·7	...	32·5	0·3	...	0·25	...	6·26
35·7	...	9·5	1·25	...	1·32	...	7·33	135·7	...	...	...	...	...	...	...

11th Aug., 1837. WAVE XCIII. Trapezoidal Channel (M).

Generated by addition of solid parallelopipedon C.
Times observed directly at γ and δ, single transits.
Time, α Russell, Index, γ Hamil, Index, δ Donaldson.

Statical level observed at $\left\{\begin{matrix} \gamma = -0{\cdot}07 \\ \delta = +0{\cdot}05 \end{matrix}\right\}$ Corrected depth = 6·01 inches.

A	B		C		D		E	A	B		C		D		E
feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.	feet.	α sec.	β sec.	γ in.	δ in.	γ' in.	δ' in.	in.
0·0	...	0·0	...	...	...	...	...	75·7	...	20·5	1·25	...	1·32	...	7·33
14·6	...	4·0	...	...	...	...	...	115·7	...	...	...	...	...	...	...
35·7	...	9·0	1·5	...	1·57	...	7·58	135·7	...	...	...	...	...	...	...

12th Aug., 1837. WAVE XCIV—CIII. Cuneïform Channel (N).

Heights observed at A = 0·, B = 8·5 feet, C = 12·75 feet, and D = 17 feet.
Breadth of Channel at A = 12 in., B = 6 in., C = 3· in., D = 0· breadth.

Statical level observed at $\left\{\begin{matrix} \gamma = -0{\cdot}25 \\ \delta = -0{\cdot}15 \end{matrix}\right\}$ Corrected depth = 3·78 inches.

Wave.	Height A.	Height B.	Height C.	Breaking Point.	Time.	Velocity.
	inches.	inches.	inches.	feet.	sec.	feet.
XCIV.	1·5	2·5	3·5	D. − 3·8	4·0	4·25
XCV.	2·0	2·4	3·3	D. − 0·0	4·0	4·25
XCVI.	2·0	2·4	3·6	D. − 2·0	4·0	4·25
XCVII.	1·25	2·0	2·5	D. − 0·0	4·0	4·25
XCVIII.	....	2·45	3·1	D. − 0·4	4·0	4·25
XCIX.	1·5	2·35	3·25	D. − 0·8	4·0	4·25
C.	2·0	2·55	3·3	{ D. − 2·0 Ht. = 3·6 in.	4·0	4·25
CI.	1·0	1·3	2·0	......	...	...
CII.	0·25	0·3	0·4	......	5·0	3·4
CIII.	...	0·5	0·65	......	...	...

12th Aug., 1837. WAVE CIV—CVI. Cuneïform Channel (N).

Heights observed at A = 0·, B = 8·5 feet, C = 12·75 feet, and D = 17 feet.
Breadth of Channel at A = 12 in., B = 6 in., C = 3· in., D = 0· breadth.

Statical level observed at $\left\{\begin{matrix} \gamma = -0{\cdot}00 \\ \delta = +0{\cdot}075 \end{matrix}\right\}$ Corrected depth = 2·01 inches.

Wave.	Height A.	Height B.	Height C.	Breaking Point.	Time.	Velocity.
	inches.	inches.	inches.		sec.	feet.
CIV.	0·25	...	0·5	2 inches high.	6·5	2·61
CV.	0·20	...	0·35	2 inches high.	6·5	2·61
CVI.	0·50	...	1·0	2 inches high.	6·25	2·64

14th Aug., 1837. WAVE CVII—CXXXII., Sloping Channel (O).
Channel 17 feet long, 4 in. deep at 0·, and 0· in. at 17 feet.

Wave.	Height at 0·.	Height at Breaking.	Distance from end.	Depth of Water at Breaking Point.
	inches.	inches.	feet.	
CVII.	0·9	1·4	6·6	1·5
CVIII.	...	2·1	9·4	2·2+
CIX.	1·1	1·4	7·6	1·7
CX.	...	2·5	11·0	2·5
CXI.	...	1·95	8·6	1·92
CXII.	0·5	0·8	5·0	1·1
CXIII.	1·5	2·3	11·0	2·5
CXIV.	1·3	1·9	8·3	1·9
CXV.	1·8?	2·2	9·4	2·2
CXVI.	1·25	1·9	8·3	1·9
CXVII.	...	2·9	15·0	3·4
CXVIII.	2·5	2·7	12·2	2·7
CXIX.	...	0·8	3·0	0·7
CXX.	1·1	1·4	6·3	1·4
CXXI.	0·2	0·3	2·1	0·4
CXXII.	1·0	1·2	5·5	1·2
CXXIII.	0·5	0·5	4·0	0·9
CXXIV.	0·8	0·8	4·3	1·1
CXXV.	0·2	0·3	2·5	0·5
CXXVI.	0·5	0·7	4·0	0·9
CXXVII.	1·2	1·7	7·5	1·7
CXXVIII.	2·0	2·7	11·3	2·6
CXXIX.	2·2	2·7	11·0	2·5
CXXX.	2·0	2·4	10·3	2·4
CXXXI.	1·5	2·0	9·0	2·1
CXXXII.	...	2·5	11·0	2·5

14th Aug., 1837. WAVE CXXXIII—CXLIX. Sloping Channel (O).
Channel 17 feet long, 4 in. deep at 0·, and 0· in. at 17 feet.

Wave.	Time from 0· to Breaking.	Whole Time from 0 to D.	Place of Breaking.	Depth of Water at Breaking Point.
	sec.	sec.	feet.	
CXXXIII.	2·0	5·5	9·3	2·2
CXXXIV.	2·0	5·5	10·0	2·3
CXXXV.	2·0	5·5	10·0	2·3
CXXXVI.	3·5	6·0	6·5	1·4
CXXXVII.	4·0	6·0	5·0	1·4
CXXXVIII.	5·0	7·0	3·9	0·9
CXXXIX.	6·0	7·0	3·0	0·7
CXL.	4·0	6·5	5·0	1·1
CXLI.	5·0	6·5	4·0	0·9
CXLII.	5·0	7·0	4·3	1·0
CXLIII.	6·5	7·5	1·5	0·2
CXLIV.	2·0	5·0	9·7	2·2
CXLV.	2·0	5·5	11·0	2·5
CXLVI.	0·5	5·5	16·0	3·7
CXLVII.	0·0	5·5*	17·0	4·0
CXLVIII.	0·0	5·5†	16·0	3·7
CXLIX.	0·0	5·5‡	15.0	3·4

* This large wave was an inch high at D, and was reflected.

† This large wave was an inch high at D, became doubled by reflection, and returned to 0 in 6·5 seconds.

‡ This large wave was 0·75 inch high at D, was reflected, and returned to O in 7·0 seconds.

Description of Plates accompanying the Report on Waves.

Plate I. contains the apparatus of the experiments on waves. Fig. 1, A is a transverse section of the experimental channel, the sides of which were made smooth and as nearly plane surfaces as possible; the whole internal surface being divided into feet, inches, tenth parts of an inch, &c., for convenient observation. B and D are the two ends of the same channel, and are elevated, so as to reflect the waves from vertical surfaces. C is the generating reservoir referred to in the experiments as "Generating Reservoir A." Fig. 2 shows the apparatus for observing transits of the wave by reflexion. I is the luminous object from which the rays falling on the plane mirror M are thrown down on the surface of the fluid at W, and thence reflected on the small mirror *m*, to the eye of the observer. W^1, W^2, and W^3, show a single wave in successive positions, and figs. 3, 4, and 5, show the places of the image corresponding to those positions. Fig. 8 shows the generation of the wave from "Reservoir A," by removing the sluice S. Fig. 9, B represents the generating chamber, resting on the bottom of the experimental channel, and containing the fluid which generates the wave when the sides of the chamber are raised from the bottom. Fig. 10 represents the solid parallelopipedon C; and that part of it towards D represents the form and magnitude of the chamber and the solid D.

Plate II. gives the forms of the waves of the sea referred to in pages 445—451 of the Report. Fig. 1, the cycloidal forms. Fig. 2, *a* and *b*, elementary waves, moving in opposite directions; *c* and *d*, the result of this combination at successive instants of time. Figs. 3 and 5 are forms observed to result from the combination of three or four co-existent classes of waves moving in different directions. Figs. 4, 5, 6 and 7 show the manner in which waves break, either from the coincidence of a wave of a higher or with the crest of a lower wave, so as to give the form of unstable equilibrium, or from the excess of the height of the wave above the depth of the fluid.

Plate III. exhibits the relation of the velocity of the waves to the depth, as taken from the experiments in the rectangular channel, fig. 1, and in the channels, fig. 2, H, fig. 3, K, and fig. 4, L. The horizontal abscissæ are depths of the fluid, and the vertical ordinates the corresponding velocities.

Plate IV. represents the form of a tide-wave as it passed

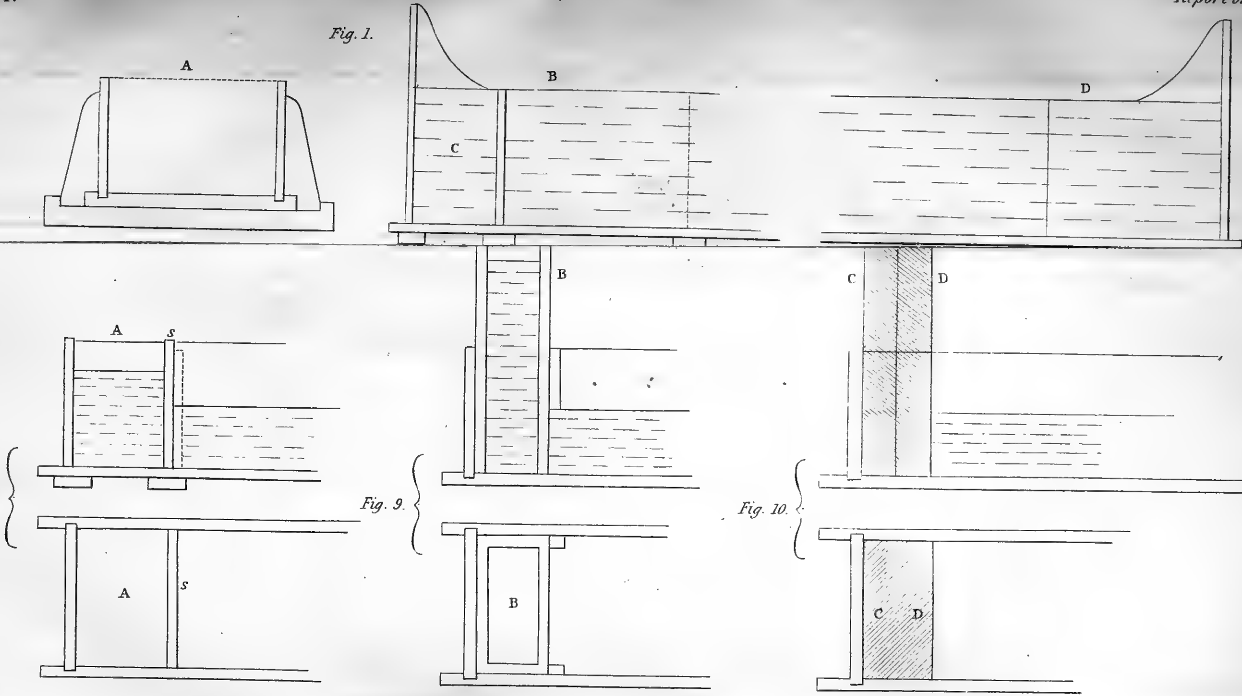
the successive stations referred to in the observations on the Clyde. The corresponding tide-wave of Liverpool Docks is given in the same plate. The stars in each wave mark its centre of length, and serve to show the increasing dislocation of the tide-wave during its ascent along the river.

Plate V. shows the line described by the summit of the tide-wave during its transit along the Frith of Clyde and the manner in which it was affected by the wind. The wave of the 3rd of May was nearly calm; and that of the 24th of April is remarkable as having been described partly during a westerly wind and partly during an easterly wind, and so falling partly above and partly below the 3rd of May, while none of the others present instances of intersection.

Plate VI. gives the form of the tide-wave of the river Dee.

Plate VII. contains the channel of the river Dee, with sections.

Plate VIII. is the channel of the river Clyde, with sections.



Lyons del^t

Lizars sc.

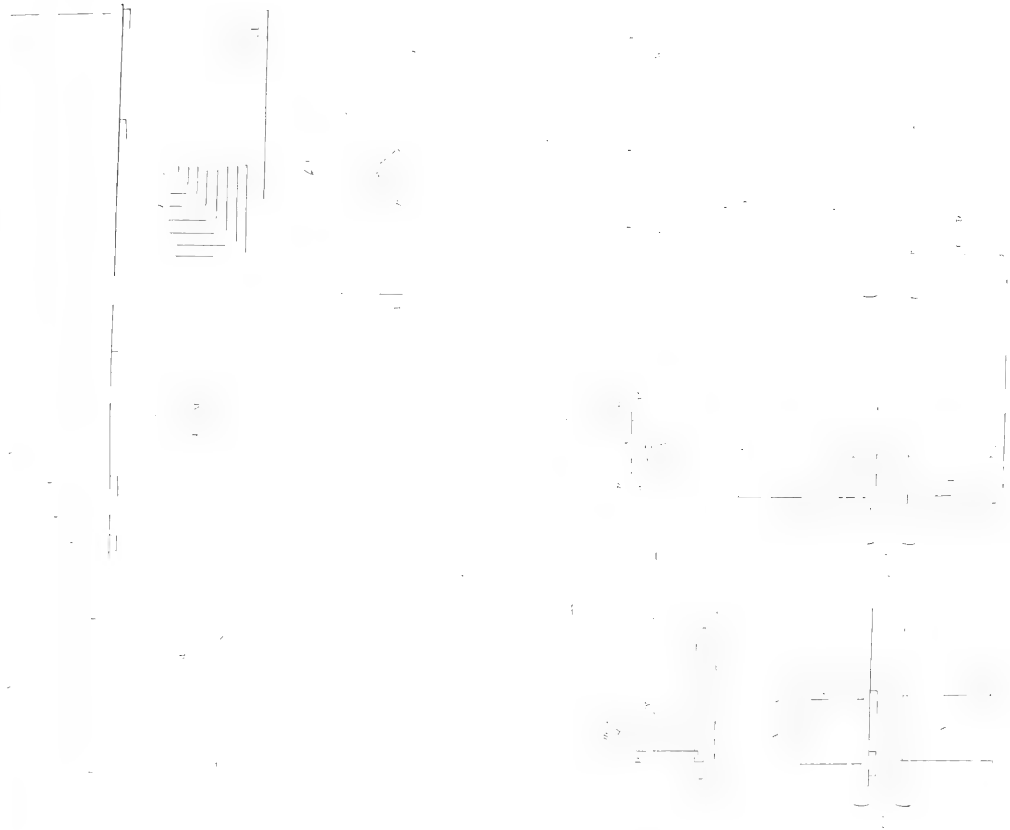
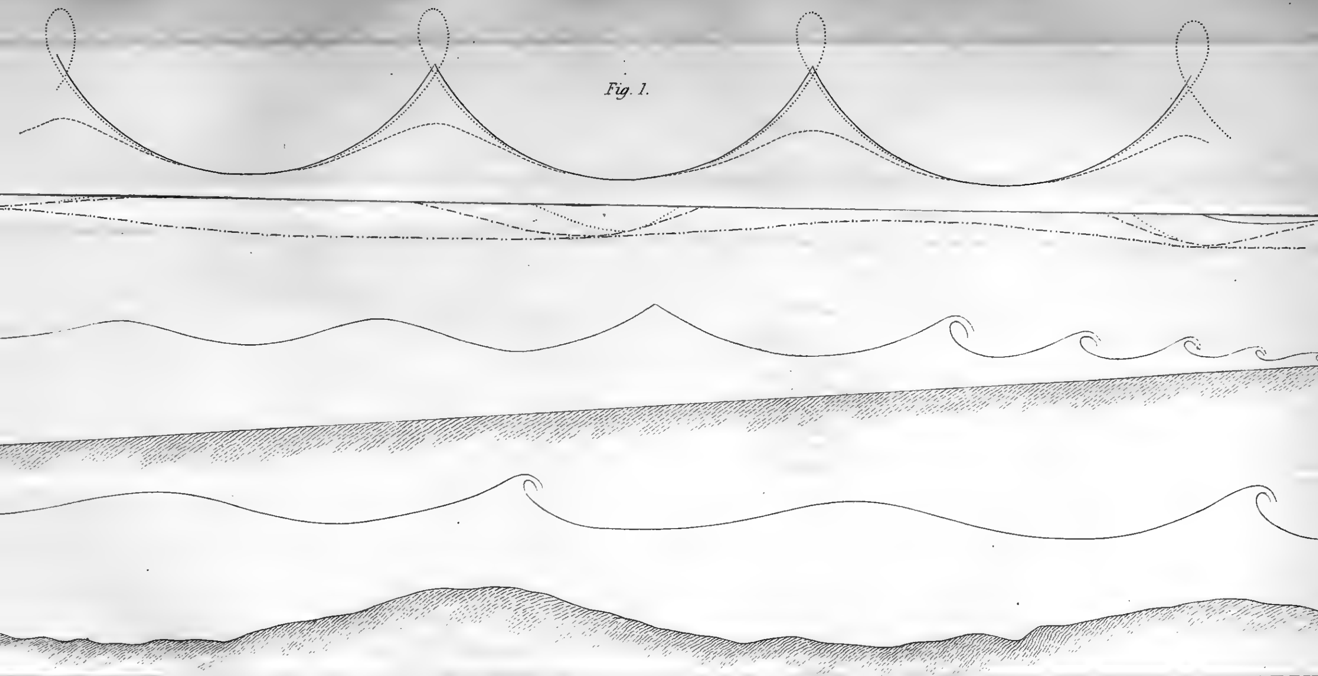


Fig. 1.



Lyons delt

Lizars sc

Fig. 1.

Fig. 2.

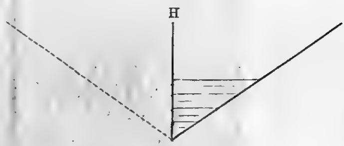


Fig. 3.

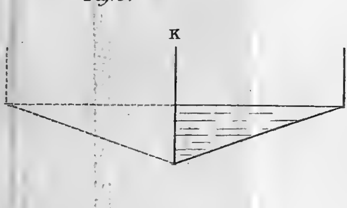


Fig. 4.

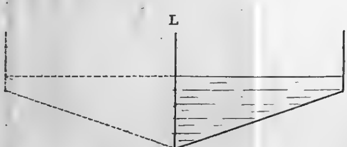


Fig. 1.

Fig. 2.

Fig. 3.

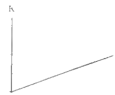
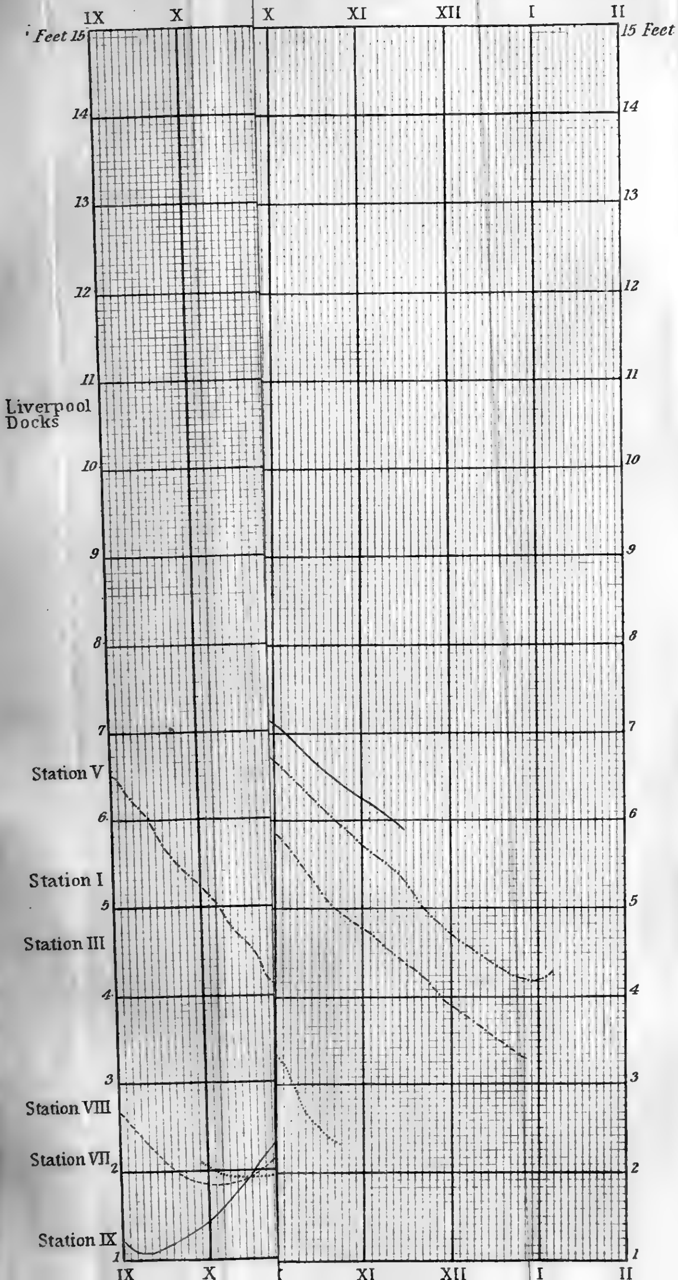
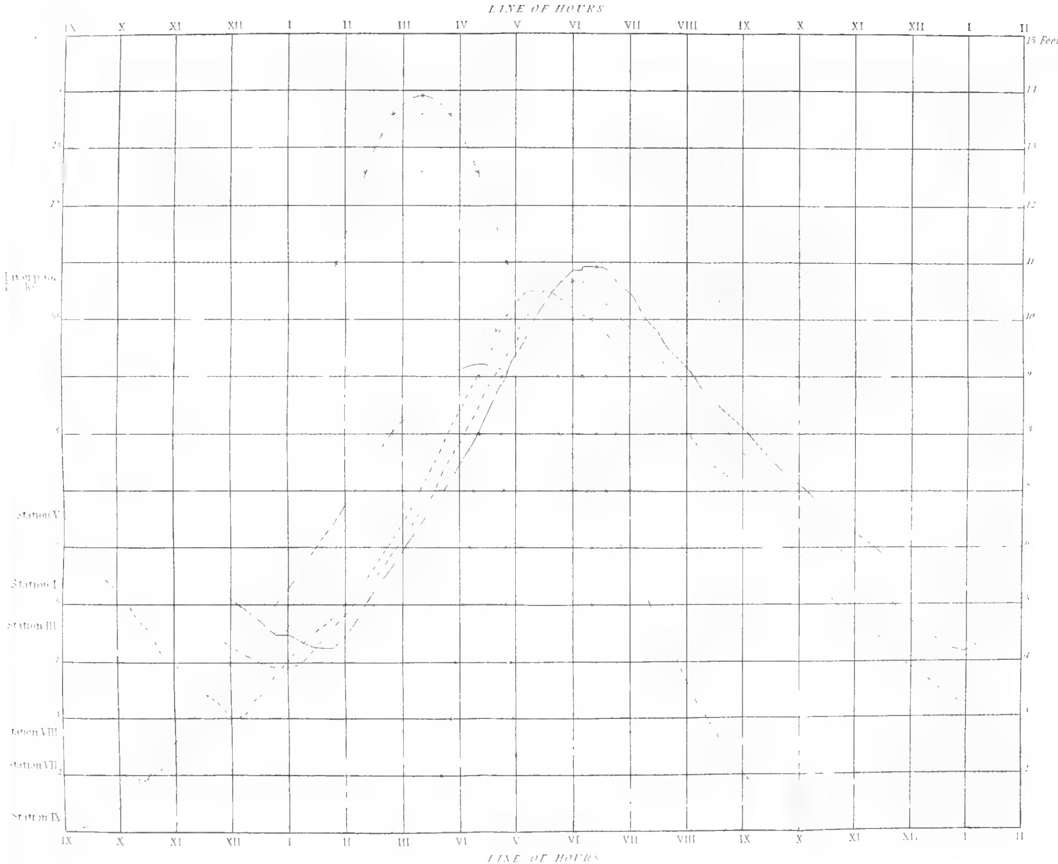
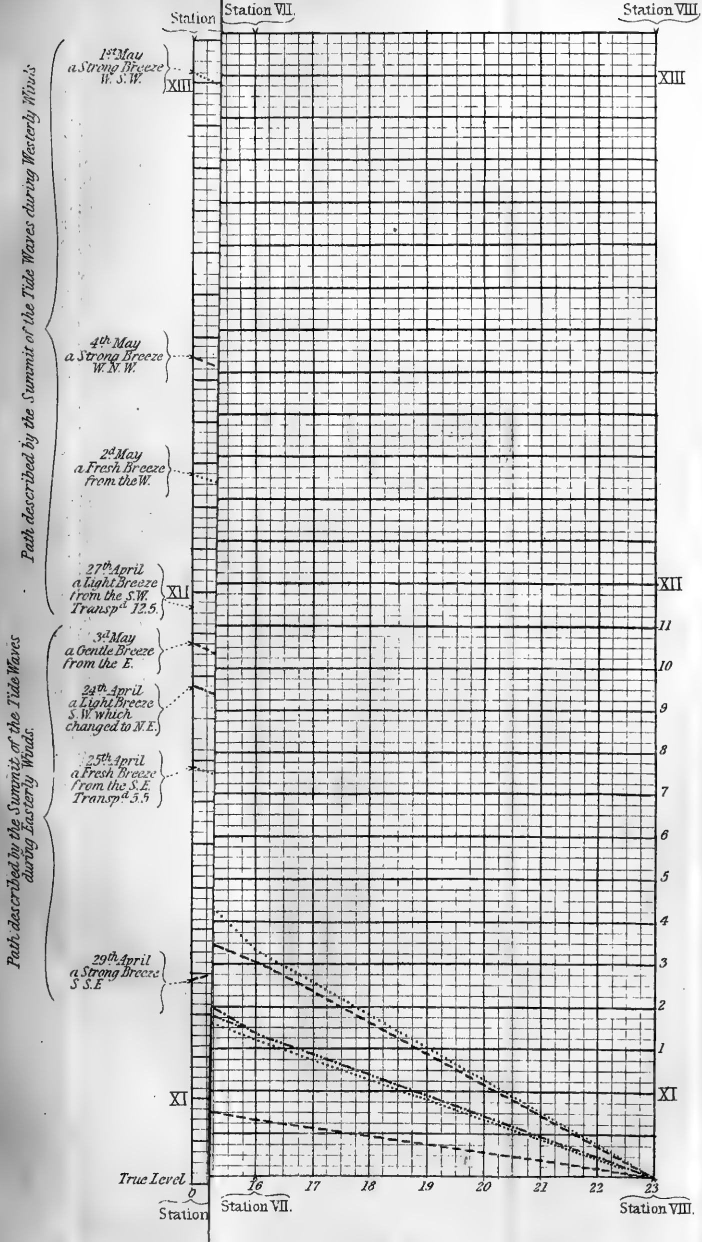


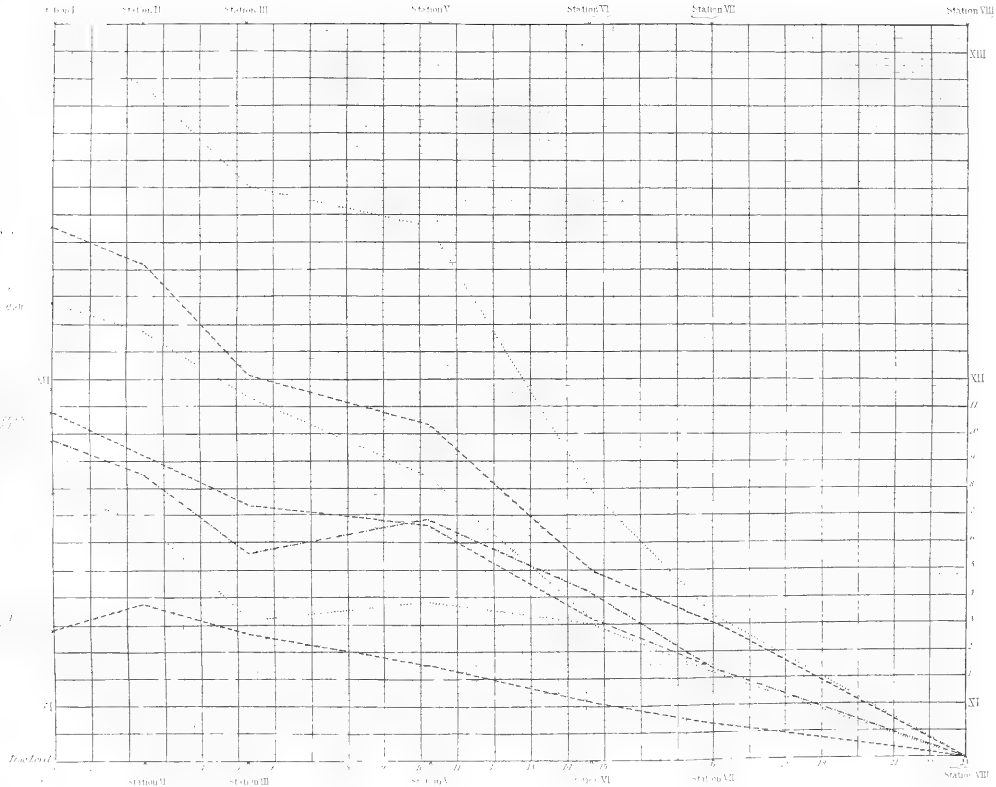
Fig. 4.


IX
X
XI
XII
I
II
Feet 15
15 Feet
14
13
12
11
10
9
8
7
6
5
4
3
2
1
Liverpool Docks
Station V
Station I
Station III
Station VIII
Station VII
Station IX


LINE OF HOURS
IX
X
XI
XII
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
I
II
15 Feet
14
13
12
11
10
9
8
7
6
5
4
3
2
Liverpool Docks
Station VI
Station I
Station III
Station VIII
Station VII
Station IX
LINE OF HOURS



Station
Station VII.
Station VIII.
Path described by the Summit of the Tide Waves during Westerly Winds
1st May a Strong Breeze W. S. W.
4th May a Strong Breeze W. N. W.
2d May a Fresh Breeze from the W.
27th April a Light Breeze from the S.W. Transpd 12.5.
Path described by the Summit of the Tide Waves during Easterly Winds.
3d May a Gentle Breeze from the E.
24th April a Light Breeze S.W. which changed to N.E.
25th April a Fresh Breeze from the S.E. Transpd 5.5
29th April a Strong Breeze S S.E
XIII
XII
XI
11
10
9
8
7
6
5
4
3
2
1
True Level
0
16
17
18
19
20
21
22
23
Station
Station VII.
Station VIII.


Station II
Station III
Station V
Station VI
Station VII
Station VIII
XIII
XII
XI
True Level
Station II
Station III
Station VI
Station VII
Station VIII

Plates
6 – 8
missing

Note by Major SABINE; *being an Appendix to his Report on the Variations of the Magnetic Intensity observed at different Points of the Earth's Surface.*

SINCE the report on the Variation of the Magnetic Intensity of the Earth, which forms the first article in this volume, was printed, I have become acquainted with a highly valuable series of observations of the magnetic intensity made by M. George Fuss, of the Imperial Academy of Sciences at St. Petersburg, in 1830, 1831, and 1832, in Eastern Siberia and China. I exceedingly regret that these most interesting determinations do not occupy their proper place in the general table of my report. I must hope, however, that being included in the same volume, they may still, to its readers, contribute their due share of experimental testimony to the system of terrestrial magnetism.

M. Fuss's observations were made in two journeys; one from Irkutzk to Pekin, in the latter part of 1830, including a return by a slightly different route the following year; the second journey was in 1832 from Irkutzk to the eastern parts of Siberia, as far as the longitude of 122° E. of Greenwich. The intensities were observed by two horizontal needles, each of which sustained a small, but uniform loss of magnetism during the period of its employment. Corrections were very carefully investigated, and have been applied on this account, as well as for changes of temperature. The details, both of the observations and the corrections, are published in the Memoirs of the Imperial Academy of Sciences of St. Petersburg, Ser. vi. vol. iii. The resulting intensities are there expressed in terms of the arbitrary scale in which Paris = 1·3482, being connected therewith by means of M. Hansteen's determinations in 1829 at Irkutzk and Kiatka, where M. Fuss also observed.

I have included in the annexed Table the variation and dip observed by M. Fuss at all his intensity stations. The dip was taken by an instrument of Gambey's, until an accident befel it at Nertschinsk, when the subsequent observations were made with an inferior instrument. The geographical positions are those given by M. Fuss.

The ground traversed by M. Fuss enabled him to observe the culminating points of the isodynamic lines of 1·5 and 1·6. These he states to be between the longitudes of 107° and

112° E. of Greenwich; and this, it will be seen, accords extremely well with the chart in this volume. In comparing the values of the intensity observed at particular stations with the chart, the intensities shown by the chart appear to be slightly in excess in the vicinity of Pekin, and in defect in the neighbourhood of the Amour River, at the eastern extremity of M. Fuss's journey; at Pekin, in latitude 39° 54′ and longitude 116° 26′, about 0·015 in excess; and at Uststretensk, in latitude 52° 20′ and longitude 121° 50′, and its neighbouring station Schegdatschinskoi, about 0·01 in defect.

Station.	Lat. N.	Long. E. from Greenwich.	Variation.	Dip.	Intensity. Paris = 1·348.
Irkutzk	52° 17′	104° 17′	1° 25′E.	68° 15′N.	1·647
Listwinischnoi	51 54	104 31	..	67 58	1·640
Stepnoi	52 10	106 21	1 8E.	68 10	1·663
Kolessowaja	52 7	106 33	..	68 10	1·666
Baingol	48 52	105 24	..	65 14	1·630
Chunzal	48 13	106 27	1 6E.	64 29	1·612
Urga	47 55	106 42	..	64 3	1·583
Nalaicha..........	47 47	107 18	..	63 39	1·591
Giltegentai........	46 54	108 46	..	63 12	1·594
Schibétu..........	46 29	109 38	..	62 34	1·609
Zsulgétu..........	46 16	110 10	..	62 38	1·565
Chologur	46 00	110 34	0 49W.	61 54	1·580
Durbanderetu	45 48	111 14	..	61 46	1·584
Ergi	45 32	111 25	1 7W.	61 22	1·559
Charatuin Sudshi ..	44 50	112 6	..	61 3	1·579
Batchay	44 21	112 55	0 59W.	60 18	1·553
Kulchuduck	43 29	113 52	..	59 14	1·538
Scharabudurguna ..	43 13	114 6	0 46W.	59 3	1·538
Zackildack........	42 48	114 17	..	58 25	1·513
Zsamein-ussu......	41 46	114 38	..	57 24	1·505
Chalgan	40 49	114 58	1 13W.	56 17	1·459
Pekin	39 54	116 26	1 48W.	54 49	1·453
Zagan Balgassu	41 17	114 44	..	56 41	1·473
Tulgha	41 33	114 44	..	57 4	1·465
Sudshi	42 28	113 51	..	58 5	1·495
Mingan	43 3	112 30	..	58 49	1·508
Zsamein Chuduck ..	43 37	111 51	..	59 22	1·509
Kutull............	43 58	111 38	..	60 13	1·520
Gaschun..........	44 23	111 19	..	60 17	1·516

Station.	Lat. N.	Long. E. from Greenwich.	Variation.	Dip.	Intensity. Paris = 1·348.
Sendshi	44° 45′	110° 26′	0° 30′W.	60° 42′N.	1·530
Kukuderissu	45 8	109 42	..	61 12	1·542
Uizsyn	45 34	109 16	..	61 44	1·543
Mogoitu	45 50	108 53	..	61 49	1·545
Chapchaktu	46 2	108 35	..	62 23	1·538
Bain Chara	46 31	107 56	..	62 59	1·582
Chapschatu	47 20	107 6	..	63 21	1·581
Urga	47 55	106 42	1 16E.	64 5	1·583
Troizkosawsk	50 21	106 45	0 1E.	66 24	1·642
Possolsk	52 1	106 18	..	68 2	1·653
Werchneudinsk	51 50	107 46	0 24E.	68 6	1·657
Kurbinsk	52 5	111 3	..	67 59	1·665
Pogromnoi	52 30	111 3	0 18W.	68 8	1·640
Tschitanskoi	52 1	113 27	1 13W.	67 42	1·668
Nertschinsk-town	51 56	116 31	2 53W.	67 11	1·635
Nertschinsk-mine	51 19	119 37	4 6W.	66 33	1·617
Zuruchaitu	50 23	119 3	3 11W.	66 13	1·626
Argunskoi	51 33	119 56	3 44W.	66 54	1·655
Uriupina	52 47	120 4	4 4W.	67 53	1·667
Schegdatschinskoi	53 15	121 21	..	68 11	1·658
Uststretensk	53 20	121 51	4 21W.	68 11	1·656
Fortress of Gorbizkoi	53 6	119 9	2 54W.	68 22	1·660
Stretensk	52 15	117 40	2 52W.	67 38	1·649
Abagaitujewskoi	49 35	117 50	2 54W.	64 48	1·583
Tschindant	50 34	115 32	2 14W.	66 32	1·650
Akschinska	50 15	113 25	..	66 40	1·671
Altanskoi	49 28	111 30	0 48W.	65 20	1·619
Mendshinskoi	49 26	108 55	0 12W.	65 31	1·630
Charazaiska	50 29	104 44	2 27E.	66 56	1·643

The extension of magnetical observations to countries so remote, and, in the case of China especially, presenting peculiar difficulties, gives the Imperial Academy of St. Petersburg an additional claim on the respect and gratitude of all who are interested in the advance of the science of terrestrial magnetism.

ERRATA.

Page 32, line 4, *omit* giving each equation a weight proportioned to the number of observations which it represents.

" 8, *for* $\delta = 68° 42'$; $r = - 0·013608$, *read* $\delta = 68° 33'$; $r = - 0·01405$, equivalent to 71 geographical miles for one degree of dip.

General Table.

Page 44.	Frazer's Lake	Intensity	*for* 1·724, *read* 1·734.
"	Stuart's Lake	"	*for* 1·736, *read* 1·745.
"	Fort Alexandria	"	*for* 1·710, *read* 1·714.
Page 45.	Multnomah River	"	*for* 1·669, *read* 1·660.
"	Sandiam River	"	*for* 1·683, *read* 1·672.
"	Columbia Rapids	"	*for* 1·679, *read* 1·671.
"	Thompson's River	"	*for* 1·710, *read* 1·701.
"	Oakanagan	"	*for* 1·707, *read* 1·701.
"	Wullawullah River	"	*for* 1·707, *read* 1·699.
Page 46.	St. Francisco	Longitude	*for* 235 45, *read* 237 35.
"	San Solano	"	*for* 235 36, *read* 237 36.
"	Monterey	"	*for* 236 00, *read* 238 00.
"	San José	"	*for* 236 00, *read* 238 00.
"	La Soledad	"	*for* 236 36, *read* 238 36.
Page 47.	San Antonio	"	*for* 236 42, *read* 238 42.
"	San Miguel	"	*for* 237 16, *read* 239 00.
"	St. Louis Obispo	"	*for* 237 20, *read* 239 20.
"	La Purissima	"	*for* 237 33, *read* 239 33.
"	Santa Ynez	"	*for* 237 49, *read* 239 49.
"	Santa Barbara	"	*for* 240 00, *read* 240 20.

And in the column of Intensities:

St. Francisco, Solano,	*for* 1·610, *read* 1·614.
San José	*for* 1·605, *read* 1·607.
San Miguel	*for* 1·583, *read* 1·580.
San Obispo	*for* 1·583, *read* 1·580.
Santa Barbara	*for* 1·604, *read* 1·587.

Report from Mr. JAMES YATES, *as one of the Committee for making experiments on the Growth of Plants under Glass, and without any free communication with the outward air, on the plan of Mr. N. I. Ward, of London.* B.

Reports on the subject of the Growth of Plants in closed Glass Vessels.

HAVING corresponded with the other members of the Committee, and ascertained that they agreed with me in wishing for the preparation of an experiment on a considerable scale, which might be exhibited at the meeting of the British Association in Liverpool, I gave instructions for the erection of a greenhouse in the yard of the Mechanics' Institute, in Mount Street. The committee of that establishment granted for the purpose the use of a convenient spot of ground 9 feet by 18 in dimensions, and with a southern aspect. It was stocked with foreign plants of all kinds to the amount of about 80 species, and placed under the care of Mr. Murray, the foreman of the Botanic Garden at Liverpool. His list of the plants, and his observations upon their state and progress, accompany this report. The general result of the experiment is, that the plants have flourished perfectly well, being in a vigorous and healthy state without any extraordinary growth. Many of them have flowered, and some of them, especially two species of *Canna* and some ferns, have ripened seed.

The greenhouse has no flue, and no provision for any artificial heat. It was judged best to construct it without a flue, both as the least expensive plan, and for the purpose of trying by a fair experiment to what extent plants may on this plan be kept alive even during the severity of winter, which would certainly die if fresh air were more freely admitted.

It is also to be observed that nothing has been done to prevent the water from escaping through the porous rock (a yellow sandstone) on which the greenhouse is erected, and hence it has been necessary to give the plants occasionally a fresh supply of water.

Since I was appointed one of this Committee I have also grown plants under glass in London, where no plant can be made to flourish without such a protection. Nearly a year ago I planted *Lycopodium denticulatum* in a chemical preparation-glass with a ground stopper. During that time the bottle has never been opened. The Lycopodium continues perfectly healthy, and has grown very much, although for want of space the form of the plant is distorted. Seeds, which happened to be in the soil,

have germinated, and Marchantia has grown of itself within the glass.

I also obtained a hollow glass globe of 18 inches diameter, and with an aperture sufficient to admit my hand for planting the specimens. A variety of ferns and lycopodiums were then set in the soil, which was properly moistened with water. This having been done, the aperture was covered with sheet India-rubber, its attachment to the glass being made perfectly air-tight. No change of air could take place except by percolation through the India-rubber, which was every day forced either outwards as the air within the glass was heated and expanded, or inwards in the reverse circumstances. These ferns grew probably as well as they would have done in a greenhouse or hothouse. They were all foreign, and some of them requiring a great heat. Several have ripened seed.

Mr. Ward's Report.

In order to render the account of my experiments on the growth of plants without open exposure to air intelligible to those who may not have seen the published statements, I will briefly mention the way in which these experiments originated. Attached to botany from my early youth, I had endeavoured to grow many plants, and particularly ferns and mosses, in and about my house, but being surrounded by numerous manufactories and enveloped in their smoke, all my endeavours proved sooner or later unavailing, owing to the necessity which I imagined to exist for exposing my plants more or less freely to the air. A simple incident at length opened my eyes, and I was led to reflect a little more deeply upon the subject. About eight or nine years ago I placed in a wide-mouthed bottle, covered with a lid, the chrysalis of a sphinx, buried in some loose mould. A week before the insect assumed its perfect form, I observed on the surface of the mould a seedling grass and fern. I saw that they required no water, as the mould continued always equally moist, from the condensation of the water on the internal surface of the glass, and it remained to be proved how far that change of air, which must of necessity result from every change of temperature, would be sufficient for the purposes of vegetable life. At all events I had gained two points, a continually humid atmosphere, free from mechanical impurities. I placed the bottle outside one of my windows, and finding that the plants grew well, I procured some hymenophyllum from Tunbridge Wells, planted it in a similar bottle, and had the pleasure to find that it likewise grew as well as in its native

situation. I then, through the kindness and liberality of Messrs. Loddiges, who well deserve the title of 'Hortulanorum principes,' commenced a series of experiments upon plants of all structures, and belonging to a great variety of natural families, which has continued uninterruptedly to the present time.

Before I proceed to state the results of these experiments, it may be as well to say a word or two respecting the cases in which they were carried on. These cases are of all sizes and shapes, from small wide-mouthed bottles to a range of houses about 25 feet in length and 10 feet in height. These houses are filled with rock work for the purpose of accommodating the various descriptions of plants I had to deal with. Some of these cases are quite closed at the bottom, and when once watered, require no further watering for a long period, while others have several openings, and the plants are watered occasionally, once in three or four weeks, or months, as they may require. I believe that this latter plan is the best, as there is then no danger from excess of wet, and should worms or slugs make their appearance, they can readily be destroyed by the free use of lime water. The glazed roofs and sides of these cases are made as tight as putty and paint can effect, and the doors fit closely. In no instance have I ever endeavoured to seal the cases hermetically; it would, I conceive, be almost impossible to do it, and if done, would prevent that continued change of air, from its alternate expansion and contraction, upon which in my opinion the success of the plan mainly depends. I have already explained myself fully upon this point in my letter to Sir W. Hooker, and should not have thought it necessary to have alluded to it again had I not seen that Professor Henslow, in his *Descriptive and Physiological Botany*, a work of the highest authority, entertains this mistaken notion. With respect to the management of the plants in the cases, I have always endeavoured to imitate their natural conditions as nearly as possible, being fully sensible of the value and truth of that remark, "that we can command Nature only by obeying her laws." It would be impossible in the necessarily short limits of this report to enter into any lengthened details, and I shall therefore give as concisely as possible the results.

1. That the change of air produced by alternate expansion and contraction is regulated by the heat, and is therefore exactly proportioned to the increased wants of the plants arising from their greater excitement. Vascular require a greater change of air than cellular plants, and this is effected by surrounding them with a larger volume.

2. It is of great importance that light be freely admitted to all parts of the growing plant, assisting it in the development

of its flowers, and enabling it to bear cold, &c. Hence the importance of protecting plants without obscuring the light.

3. Owing to the perfectly quiet condition of the air in these cases, plants will bear variations of temperature which under ordinary circumstances would prove fatal to them. Thus I have found that many palms, ferns, and numerous Cape and Australian plants bear the cold of our climate with impunity, while others, when exposed to heat, become surrounded by a protecting atmosphere of their own creation, as, for instance, the *Trichomanes brevisetum*, which has been growing for the last three years in a case in my drawing room, fully exposed to the south, and in which the thermometer frequently rises to 100°. A more striking illustration of this may be adduced in a case of plants brought by Captain Mallard, from New Holland. The plants were inclosed in February, thermometer being 94° in the shade. In rounding Cape Horn two months subsequently the thermometer fell to 20°; a month after this it rose again to 100° in the harbour at Rio; in crossing the line the thermometer attained 120°, and fell to 40° on their arrival in the British Channel in November, eight months after they were inclosed. These plants were taken out in the most healthy condition.

4. These cases enabling us to surround our plants for an indefinite period, with an atmosphere of any required humidity, we are enabled to grow in any situation, even on our study tables, a great number of plants, the growth of which has hitherto been in great measure confined to their native woods and wilds. To notice one instance; I had been struck with the published accounts of the very rapid growth of some fungi, and particularly of *Phallus fœtidus*, which was said to attain its height of four inches in as many hours. I procured three or four specimens in an undeveloped state and placed them in a small case. All but one grew during my temporary absence from home. I was determined however not to lose sight of the last, and observing one evening that there was a small rent in the volva, indicating its approaching development, I watched it all night, and at eight in the morning the orifice of the pileus began to push through the jelly-like matter with which it was surrounded. In the course of 25 minutes it grew three inches, and attained its full elevation of four inches in one hour and a half. It can hardly be conceived that in this case there was any actual increase of matter, but merely an elongation of the erectile tissue of the plant.

I think it is quite needless to point out the various important applications of the above facts to the growth of plants in towns, their conveyance and growth on ship-board, or the numerous

physiological inquiries which may now be made with much greater facility and certainty than heretofore; but I wish to direct the attention of the members of the British Association to the development of animal life upon the same principles. I am quite certain that a great number of animals would live and thrive under this treatment, and I can see no reason why, at the same time that our stoves are ornamented with Rafflesias, they may not be illuminated with Fulgoras and Candelarias.

Letter from Messrs. Loddiges to Mr. Ward.

Hastings, 8th Sept., 1837.

Dear Sir,

We have much pleasure in stating, that among the many cases of plants which we have received during the last three or four years, wherever your instructions have been strictly attended to, the success has invariably been complete; the failures which have occurred have been where neglect had manifestly taken place, either by keeping them in the dark, or in some cases by breaking the glass. We remain, dear Sir,

Very sincerely yours,
C. Loddiges & Sons.

On the Growth of Plants confined in Glass Vessels. By Dr. Daubeny, *of Oxford.*

To James Yates, Esq., Secretary to the Council of the British Association for the Advancement of Science.

Oxford, July 1st, 1837.

Dear Sir,

As it will not be in my power to attend the meeting at Liverpool, I am desirous of communicating to you the results of a few experiments which I have undertaken with reference to the growth of plants confined in glass vessels, as a proof at least that I have not altogether neglected the researches recommended by the Association to the attention of the Committee of which we are joint members, although the preparations for a journey into a distant land have very much curtailed my opportunities of prosecuting them.

During the last week in April I introduced a considerable number of living plants into glass globes, having only a single aperture through which air could circulate, and that one covered over by a sound piece of bladder closely attached to the edges of the glass, so as to preclude the possibility of any air entering the vessel except through the membrane itself.

The following were the plants introduced into these vessels :

In glass 1 were *Sedum rupestre* and *telephium*, *Veronica repens*, *Gentiana acaulis*, *Erigeron bellidifolius*, *Lobelia fulgens*, *Saxifraga virginiana* and *irrigua*.

In glass 2 were *Primula vulgaris*, *Anemone nemorosa*, *Pulmonaria angustifolia*, *Alchemilla vulgaris*, *Valeriana dioica*, *Veronica repens*, *Lobelia fulgens*.

In glass 3 were *Primula veris* and *auricula*, *Erigeron bellidifolius*, *Dianthus armeria*, *Sempervivum montanum*, and *Lobelia fulgens*.

Now these plants were allowed to remain till May 5th, a period of almost 10 days, undisturbed, at the end of which time they appeared healthy and had grown considerably ; some even had flowered since their introduction.

The air contained in each jar was then examined during the day, a portion of it having been drawn off into an exhausted tube through a stop-cock connected with the jar.

In this manner it was ascertained that the air in jar 1 contained 4 per cent. of oxygen more than the proportion present in atmospheric air ; in jar 2, $1\frac{1}{2}$ per cent. more ; in jar 3, 2 per cent. more.

At night, on the contrary, this excess of oxygen had disappeared, the air examined three hours after sunset corresponding in every case as nearly as possible with that present in the atmosphere.

The following day (May 6th) the results were not equally favourable, yet even then in jar 1 there was an excess of 2 per cent. of oxygen ; in jar 2 an excess of 1 per cent. ; in jar 3 of 2 per cent., and this excess was plainly attributable to the action of light, for it in a great measure disappeared when the jars were left in the dark for a few hours, No. 1 under this treatment being found to contain just the quantity present in the atmosphere, and No. 2 only 0·75 more.

It would seem then that for a certain period plants have the power of thriving and adding to the amount of oxygen, even under the circumstances detailed ; but that there is a limit to this power appeared on a re-examination of the air three weeks afterwards (viz., on May 25th), when it was found that jar 1 contained only 1 per cent. more oxygen than that in the atmosphere instead of 4, as on the 5th instant, and that jars 2 and 3 even contained a portion less.

Examined again on June 20th, No. 1 was found to contain $2\frac{1}{2}$ per cent. less of oxygen than that in atmospheric air ; No. 2, $3\frac{1}{2}$ less ; No. 3, 4 per cent. less. We seem therefore

to have reached the lowest degree of aerial circulation under which plants will continue to live and thrive, although even this slow transmission of air was sufficient to their vitality, rendering it only less vigorous and healthy.

To ascertain then what the degree of circulation through the substance of the membrane in these instances might have been, I removed from one of the jars the plants and vegetable mould it had contained, and substituted for them about an equal amount of dry sand. I then passed through the vessel a current of oxygen until the volume of air within contained no less than 77 per cent. of that gas. The air was then examined again at 4 p.m., after an interval of three hours from the period of the first experiment, and found to have lost 4 per cent. of oxygen. The jar was then put aside till eight o'clock the next morning, when it was found to contain only 63 per cent. of oxygen, having diminished in 16 hours 10 per cent. After having been exposed all day to air and light, and examined at eight the same evening, the oxygen was found to amount to only 46 per cent., having diminished in 12 hours 18 per cent. During the next night it had diminished in 12 hours only 6½ per cent., the amount of oxygen existing in it the next morning being 38½ per cent. During the next day it had lost 7 per cent., containing at eight in the evening 31½ per cent. The next night the diminution was only 2½ per cent., and on the succeeding day 3 per cent. The following night the diminution was 1½ per cent., the amount of oxygen being 24½ per cent. only. During the day a further diminution of 3½ per cent. took place, the air inclosed within the jar being found to contain exactly the quantity of oxygen present in atmospheric air.

The following is a tabular view of the results:—

June 23rd 1 p.m.	amount of oxygen	77·	excess	56·
4 p.m.	———	73·	——	52·
24th 8 a.m.	———	63·	——	42·
8 p.m.	———	45·	——	24·
25th 8 a.m.	———	38·5	——	17·5
8 p.m.	———	31·5	——	10·5
26th 8 a.m.	———	29·0	——	8·0
8 p.m.	———	26·0	——	5·0
27th 8 a.m.	———	24·5	——	3·5
8 p.m.	———	21·0	——	0·0

Thus five days were required to enable the whole excess of oxygen to pass through the substance of the membrane, the diameter of which was 3 inches, whilst the capacity of the vessel, when the sand had been introduced, was nearly one gallon, so that about three quarts of oxygen and one of nitrogen may be

calculated as having been present in the jar at the commencement of the experiment, of which about $4\frac{1}{2}$ pints were discharged through the membrane in the course of the five days during which the observations were continued.

The transmission took place more rapidly during the day because of the exposure of the jar to the sun and wind, which by the expansion caused within the vessel, and by the more rapid succession of aerial currents brought into contact with the external surface of the membrane, doubtless caused in a greater degree the transmission of the redundant oxygen. The average quantity that escaped per diem did not much exceed 11 per cent., or did not quite amount to one pint in the 24 hours, but of course the transmission was more rapid at first, and diminished gradually in quantity as the evaporation of the air within the jar approached more nearly to that of the atmosphere surrounding it.

Believe me, dear Sir, yours faithfully,

CHAS. DAUBENY,

Professor of Chemistry and Botany, Oxford.

END OF THE REPORTS.

NOTICES

AND

ABSTRACTS OF COMMUNICATIONS

TO THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE,

AT THE

LIVERPOOL MEETING, SEPTEMBER 1837.

ADVERTISEMENT.

The Editors of the following Notices consider themselves responsible only for the fidelity with which the views of the Authors are abstracted.

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OF

MISCELLANEOUS COMMUNICATIONS

TO THE SECTIONS.

MATHEMATICS AND PHYSICS.

Exposition of the Argument of Abel, respecting Equations of the Fifth Degree. By PROFESSOR SIR W. R. HAMILTON, *Pres. R. I. Academy.*

THIS Exposition will be published in the Second Part of the XVIIIth Volume of the Transactions of the Royal Irish Academy; and a Sketch of it has been already printed in the 5th Number of the Monthly Proceedings of that Academy, for the year 1836–7.

On New Applications of the Calculus of Principal Relations. By PROFESSOR SIR W. R. HAMILTON, *Pres. R. I. Academy.*

After the reading of this paper the author was requested by the General Committee to report to the next Meeting on the applicability of his Calculus of principal relations to the theory of the Moon's motions.

An Exposition of Mr. Turner's Theorem respecting the Series of Odd Numbers and the Cubes and other powers of the Natural Numbers. By PROFESSOR SIR W. R. HAMILTON.

On some New Properties of Geometric Series.

By Charles Blackburn, A.B.

This paper consisted of a series of geometric theorems, of a somewhat novel character; but from its length and abstract nature did not admit of being read to the Section. The author explained one of the theorems, and in a brief statement enumerated some of the purposes to which they are applicable.

It appeared that the paper contains formulæ,

1. For finding the products of a variety of factors of particular forms.
2. For reducing expressions hitherto considered fractional to integers.
3. For reducing fractional expressions to equivalent ones, of which the terms shall be, of m and n less dimensions; or to other equivalent fractions of more convenient forms.
4. For the resolution of geometric series into any proposed number of factors.

Of the first kind of theorems, the 2 following are given as examples.

(1)

Let m and n be whole numbers, x and y any quantities; then

$$x^{m^n-1}+x^{m^n-2}y+x^{m^n-3}y^2+\ldots\ldots x^2y^{m^n-3}+xy^{m^n-2}+y^{m^n-1}$$

$$=\left\{x^{m-1}+x^{m-2}y+x^{m-3}y^2+\ldots\ldots\ldots\ldots\ldots\ldots x^2y^{m-3}+xy^{m-2}+y^{m-1}\right\}$$

$$\times\left\{x^{m(m-1)}+x^{m(m-2)}y^m+\ldots\ldots\ldots\ldots\ldots\ldots+x^m y^{m(m-2)}+y^{m(m-1}\right\}$$

$$\times\quad \cdot\ \cdot$$

$$\times\left\{x^{m^{n-1}(m-1)}+x^{m^{n-1}(m-2}y^{m^{n-1}}+\ldots x^{m^{n-1}}y^{m^{n-1}(m-2)}+y^{m^{n-1}(m-1)}\right\}$$

(2)

Let $m\,n\,p$, &c. $=$ N, then

$$x^{N-1}+x^{N-2}y+x^{N-3}y^2+\ldots\ldots x^2y^{N-3}+xy^{N-2}+y^{N-1}$$

$$=\left\{x^{m-1}+x^{m-2}y+x^{m-3}y^2+\ldots\ldots\ldots\ldots x^2y^{m-3}+xy^{m-2}+y^{m-1}\right\}$$

$$\times\left\{x^{m(n-1)}+x^{m(n-2)}y^m+\ldots\ldots\ldots\ldots\ldots\ldots+x^m y^{m(n-2)}+y^{m(n-1)}\right\}$$

$$\times\left\{x^{mn(p-1)}+x^{mn(p-2)}y^{mn}+\ldots\ldots\ldots\ldots+x^{mn}y^{mn(p-2}+y^{mn(p-1)}\right\}$$

&c. &c. &c. &c.

Other theorems will probably appear in some other scientific publication.

On the Parallax of α Lyræ. By the Rev. DR. ROBINSON.

The observations of the late Dr. Brinkley, he observed, with an eight-feet circle, indicated a parallax of about $1''$ for α Lyræ; but Mr. Pond, with the Greenwich mural, appeared to obtain contradictory results. His observations seemed so satisfactory, that the Royal Society considered the question as completely decided, and rewarded him with their medal. It is true that the Society afterwards seemed to retract this opinion, by awarding the same honour to Brinkley himself; but the impression remained on the public mind. Dr. Robinson should not have noticed this, but that he observed, in some late addresses, that this opinion was sanctioned by the illustrious names of Airy and Peacock. In reducing the Greenwich observations for the nutation, he had many of α Lyræ, and, selecting those which were near the maxima and minima of parallax, he obtained the following values of the constant of parallax:—

Parallaxes of α Lyræ resulting from Mr. Pond's Observations.

		Parallax.	No. of Observations.
Summer	1812·5	−0·07	29
Winter	1817	−0·70	33
Winter	1819·0	−0·77	33
Summer	1819·5	−1·08	22
Winter	1820·0	+1·73	18
Winter	1822·0	−3·65	16
Winter	1827·0	−1·01	21
Summer	1827·5	+0·17	70
Winter	1828·0	−0·18	30
Summer	·5	−0·23	52
Winter	1829·0	+2·82	26
Summer	·5	+0·99	22
Winter	1830·0	−1·84	9
Summer	·5	+0·90	22
Winter	1831·0	+0·07	23
Summer	·5	+1·30	29

Combining and expressing by d^2n the error of nutation, and by dm the error of prop. motion.

1812, 1818, 1822	par $=-1·28-0·8\,d^2n+0·3$dm.		78 obs.
1819	$=-0·95$	$-0·3$	55
1827	$=-0·42$	$-0·2$	91
1828	$=-0·20$	$-0·25$	82
1829	$=+1·91$	$-0·3$	70
1830	$=-0·47$	$-0·25$	31
1831	$=+0·68+0·05d^2n$	$-0·3$	52

in which it is supposed that $d^2n=-0·31$; dm. $=+0·07$, assuming Bessel's proper motion to be true.

These results obviously may give any parallax, and, therefore, as far

as they go, the question must be considered as perfectly open,—or, rather, they indicate that the Dublin circle has, to the present time, given consistent results, which have not been disproved.

Dr. Robinson pointed out the necessity, in such inquiries, of guarding against the errors proceeding from changes of temperature, which may occasion a diurnal change, capable, in some cases, of masking the parallax, supposing it given by the instrument. He stated that he had examined the index correction of his own circle by observing the Pole star and δ Ursæ minoris at both culminations on the same days; and that, though the German astronomers were always attentive to detect such changes, it was not, as far as he knew, generally practised in Britain.

On Tides. By the Rev. W. Whewell, *F.R.S., &c.*

Mr. Whewell observed that his own researches agreed with those of Mr. Lubbock, both in giving a very close and remarkable coincidence of the laws of observation and theory on most points, and also in disclosing some curious discrepancies of some of the features of the observed tides from the theoretical*. In particular, he stated that he had satisfied himself, as Mr. Lubbock had done, but by independent investigations, founded on quite different facts, that the *diurnal inequality* was very different at different points of the same coast; and that at places not very distant from each other, he had found cases where this inequality was absolutely inverted, making *that* the lower of two successive tides, which, at a period of their progress a little anterior, had been the higher. He stated that this circumstance, having attracted his attention, he had, in a postscript to his *seventh* series of Tide Researches, printed in the Philosophical Transactions, offered a certain hypothesis as a mode of accounting for it—namely, that the tides might be conceived as transmitted by *transverse* undulations; and, he added, that subsequent researches, about to be published in his *eighth* series, had shown him that he must entirely retract this hypothesis. He added also, that he was able to say the same of another hypothesis, at first sight very plausible—namely, that the diurnal tide travels at a *different rate* from the common semi-diurnal tide. He stated, that having taken sixty of the best-conditioned places on the coasts of Great Britain and Ireland, for the purpose of tracing the progress of this diurnal inequality, he had had the requisite calculations made by calculators (Mr. Dessiou and Mr. Ross) placed at his disposal by the Admiralty. He had separated the *diurnal wave* from the semi-diurnal tide, by examining the comparative influence of the diurnal inequality upon high and upon low waters. He had pursued this diurnal wave *first* along the west coast of Ireland, round the north of Scotland, and down the east coast of Scotland and England; and he had found that the diurnal wave never gained or lost much in its rate of progress compared with the semi-diurnal. This was generally two or three hours behind, sometimes

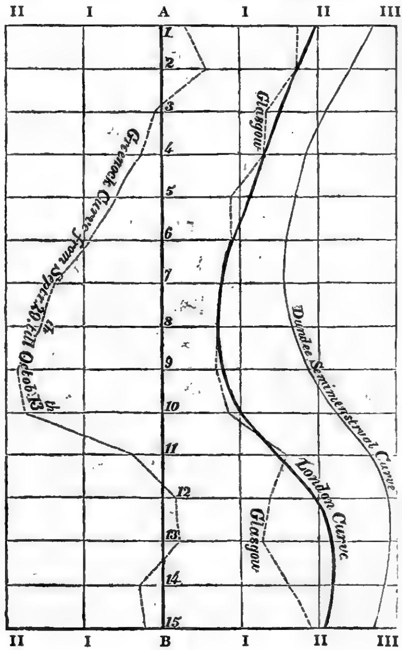
* See p. 103.

more than five, sometimes less than two, but with no *progressive* difference. He had *next* followed another diurnal wave up the Channel, and had found the same general approximation from the Land's End and Brest to the Isle of Wight; but in the Southampton waters, and so on to Portsmouth, the diurnal wave was thrown out of its course so much as to affect the tides in a reverse order to that which took place in the previous part of its course; so that if two successive tides, A, B, progressed from Bridport to Southampton, A was higher than B at the first place, and B higher than A at the second. He referred also to the *double tides* (four in twenty-four hours) which occur in the Solent Sea, and invited the attention of persons residing in the neighbourhood of those coasts to the investigation of this subject, since such persons can best determine over what extent of coast this double tide prevails—how, at the extremities of its range, the double tide grows out of the single—at what intervals the two tides occur—which is the greater, and how these relations vary at different places,—and whether these changes can be connected in a definite manner with the tidal currents. He added that, in some places, instead of four or two tides in the twenty-four hours, there appears to be only *one*, especially on the coasts of Australia. He observed, that he conceived he had already evidence to show that these supposed *single day tides* were, in fact, only extreme cases of great diurnal inequality; and he stated that the Admiralty, in pursuance of suggestions made by him, through Captain Beaufort, the hydrographer, had directed observations to be made at several points on the coasts of Australia, which he hoped would enable him to decide this question, and to draw from them the laws of such cases.

On the Tides of Dundee and Glasgow. By DAVID MACKIE, *Lecturer on Natural Philosophy, Glasgow Mechanics' Institute.*

The author of this paper having been solicited about three years ago to furnish tide-tables for Dundee and Glasgow, was led to compare the results of his calculations with the actual times of high water at these ports. From the great discrepancies frequently observable, the data made use of necessarily became extremely dubious. With the view of obtaining correct data, and of co-operating, as far as in his power, with the eminent individuals who have recently given a new impulse to such inquiries, he was fortunate in inducing Lieutenant Smart, harbour-master, Dundee, to undertake a series of observations on the tides at that port, while at Glasgow he undertook a similar series of observations himself. The observations of Lieutenant Smart were continued from January 1st till September 3rd, 1837. They include the time and height of the tide morning and evening, the state of the barometer and thermometer, and the character and direction of the wind. At Dundee, the interval of time at which the tide follows the meridian passage of the moon, on the days of full and change, is subject to considerable variation, sometimes being only 2 hours, and at other times 3 hours; but by taking the average of all the intervals which occurred between the time of high water and the moon's northing or southing, from new till full, during the

period over which the observations extend, it was found to amount to 2 hours 48 minutes, being 33 minutes greater than the time of high water at full and change, as given for Dundee in the Nautical Almanac. The "vulgar establishment" of that port is therefore 2 hours 48 minutes. As at London, Bristol, Liverpool, and other places where good observations have been made, so at Dundee, the interval of time between the meridian passage of the moon and the occurrence of high water is greatest about new and full moon, and decreases till about the seventh and eighth days after these periods. This inequality in the intervals alluded to has been appropriately termed, by Mr. Whewell, the "semi-menstrual, or half-monthly inequality;" and if we draw a line, and erect upon it fifteen equidistant ordinates or perpendiculars, to represent, by their comparative lengths, the fifteen different intervals which occur between the time of high water and the moon's northing and southing, from full to change, the line joining the extremities of the ordinates generally forms a pretty regular curve. According to Mr. Lubbock and Mr. Whewell, if we perform such an operation with the intervals between the time of high water and the moon's meridian passage at London, from full to change, we obtain the curve represented by the boldest line in the following diagram.



Upon taking, *singly*, any of the fifteen intervals which occurred at Dundee, and laying them down as ordinates, the line joining their extremities was not found to form a perfectly regular curve. The tides being influenced by the particular direction and velocity of the wind, are sometimes retarded and sometimes accelerated, so that ordinates representing the intervals must occasionally be longer and shorter than they would be in the absence of such a source of disturbance. The author, however, found, to his great satisfaction, that upon taking the averages of all the intervals corresponding to the same parallaxes and declinations, a perfectly regular curve resulted, very similar in form to that for London, only running much higher. This semi-menstrual curve for Dundee is represented by the fainter line crossing the diagram. In the following table, the fifteen intervals for London occupy the second column, and those for Dundee the third column.

Moon's Age.	Tide after Moon's Transit at London.		Tide after Moon's Transit at Dundee.		Difference.	
Days.	h	m	h	m	h	m
1	1	57	2	42	0	45
2	1	45	2	26	0	41
3	1	32	2	6	0	34
4	1	19	1	50	0	31
5	1	6	1	45	0	39
6	0	54	1	35	0	41
7	0	46	1	35	0	49
8	0	43	1	40	0	57
9	0	45	1	49	1	4
10	1	1	2	15	1	14
11	1	27	2	40	1	13
12	1	57	2	52	0	55
13	2	8	2	55	0	47
14	2	10	2	49	0	39
15	2	4	2	40	0	36

From the fourth column of this table it appears that the intervals of time between the meridian passage of the moon and the time of high water at Dundee exceed the corresponding intervals at London, from 31 minutes to 1 hour 14 minutes. The "corrected establishment" for any place, according to Mr. Whewell, is the mean of the intervals which occur between the meridian passage and the times of high water. At Dundee, therefore, the corrected establishment is 2 hours 15 minutes, which, it is rather singular, happens exactly to agree with the time given in the Nautical Almanac for high water at full and change. As to the existence of a diurnal inequality, either in the time or height of the tides at Dundee, he did not consider the obser-

vations sufficiently numerous to warrant him to draw any general inference, but simply remarked, that in January there were twenty-six of the evening tides higher than those of the morning, in February nineteen, in March twenty-four, in April twenty-four, and in May nineteen. In June the morning tides began to take precedence in point of height, there being in that month eighteen morning tides higher than those of the evening, in July twenty-one, and in August twenty-four. So far as the observations went, there did not appear to be any connection between the height of the tides and the pressure of the atmosphere, as indicated by the barometer.

The observations on the tides at Glasgow were continued by Mr. Mackie for five months, though these months were not continuous. From these observations he deduces the "vulgar establishment" at that place to be 1 hour 43 minutes, and the "corrected establishment" 1 hour 9 minutes. With regard to the intervals between the meridian passage of the moon and the time of high water, although they are greatest about new and full moon, and decrease till about the seventh and eighth days after these periods, they are subject to very great irregularities; to such an extent is this case, that he had not been able to extract from the five months' observations a regular curve for the semi-menstrual inequality. In the former diagram the light dotted line represents the genuine curve obtained from the five months' observations: it is probable that, when fully determined, it will run a little below that for London for the four or five first intervals after new moon, gradually, however, approaching, till it coincides nearly for the sixth, seventh, eighth, and ninth intervals, when it will again gradually diverge and terminate somewhat below that for London.

The river Clyde has undergone very great alterations in its channel, even within the last fifty years; and as it is of the utmost importance to have a record of the influence produced on the progress of the tide, by alterations in the breadth, depth, and form of the channel of a river, the following brief detail of the modifications in the channel of the Clyde, and the effects which have ensued, may serve as a precedent in directing, so far, those who are entrusted with the improvement of the navigation in other rivers. About the commencement of the sixteenth century the river was entirely in a state of nature. Its banks were in general flat and low. The channel abounded with shoals and fords, at some of which the tide, at high water, was not above 3 feet, and at low water about $1\frac{1}{2}$ feet. The lowness of the banks permitted the tide to spread over a great extent of surface, forming pools and islands, among which the most experienced skippers could not always distinguish the real channel. In this state the celebrated engineer Smeaton found the river, when solicited by the magistracy to report upon the best method of improving it, in 1755. At this period the breadth varied greatly from Glasgow to Bowling Bay, a distance of about ten miles. The breadth at Glasgow, immediately below the Broomielaw, was about 500 feet; and although, further down, it was in some places less, it upon the whole increased,

till at Bowling Bay the breadth was at least one half mile. The river is now contracted by a sloping ruble embankment on each side, and decreases from 163 feet wide at the Broomielaw, to 530 at Bowling. Great alterations have also been made upon the depths. The contraction of the channel has been one means of accelerating the current, and thereby scouring and deepening the river; but, in addition to this natural agent, numerous dredging machines, worked by steam, have been employed; and, within the last eighty years, the *general* depth has been increased from 4 to 16 feet. In Mr. Smeaton's Report, already alluded to, the utmost contemplated by his improvements was to enable a vessel of 100 tons burthen to get up to the Broomielaw, and that partly by the use of locks. In 1806 it was thought worthy of recording in Mr. Telford's report, that Captain Wilkie, of the Harmony of Liverpool, sailed up to Glasgow, the vessel being 120 tons burthen, and drawing 8 feet 6 inches water; and it is mentioned, in Dr. Clelland's Annals of Glasgow, that in the same year a heavy-loaded schooner, 150 tons burthen, came direct from Liverpool, and discharged her cargo at the Broomielaw. At present, very large steam-boats and vessels, of 300 tons burthen, may freely venture up the river at high water.

Alterations which have produced such important effects in facilitating the navigation of the Clyde must also have tended materially to give free access to the tidal wave, render its progress more rapid, and enable it to ascend further up the channel. It is, however, deeply to be regretted, that on account of no register of the tides having been kept at Glasgow, or at any other place on the river, it is impossible to discover what have been the *precise* effects of such important alterations. From 1755 till 1834, the practical knowledge and genius of Smeaton, Golbourne, Watt, Telford, Rennie, and others, have been called into exercise, in devising schemes for improving the navigation of the river; but on examining their reports, amounting to seventeen in number, although they sounded the river repeatedly at high and low water, and state the *day*, it will be found that the *time* of high water, at two different places on the river, is only once mentioned; this is in Mr. Golbourne's Report, dated November 30th 1768, where it is stated that the tide at new and full moon occurred eighteen miles below Glasgow, or at Port Glasgow at noon, and at the Broomielaw at two, making the tide two hours later at Glasgow than at Port Glasgow. Assuming this as the difference which existed at that period between the times of high water at these two places, the author can pretty confidently assert, that *in calm weather* the difference now is generally only about 1 hour 16 minutes; but it increases from this amount, upwards, to nearly 2 hours, according to circumstances. Previous to the improvements in the channel neap tides were hardly perceptible at Glasgow bridge, and they are now sensible about three miles further up the river. These statements are derived from numerous observations made by the author and several of his scientific friends. The chief object in view was to obtain correct data for tide

calculation; but it is hoped that the results will enable the eminent individuals who take the lead in such inquiries, to connect Glasgow and Dundee with the other ports around Britain, at which good observations have been made.

It is a singular circumstance, that the time of high water at Port Glasgow and Greenock generally *precedes* the meridian passage of the moon instead of following it. This was evident from observations made before the meeting of the Association; but since that period the author has been furnished with observations made at Greenock with great care, under the superintendence of Mr. James Thomson, civil engineer; and in the former diagram the zig-zag line on the left represents the intervals between the meridian passage of the moon and high water, from new moon September 29th, till full moon October 13th, 1837. When the curve is on the right of the vertical line A B, the times of high water are after the moon's southing; but when on the left, they precede the moon's southing, and to an extent sometimes of nearly 2 hours.

On an Optical Phænomenon observed at Mont Blanc. By M. DE LA RIVE.

When the sun has set at Geneva, it is observed that Mont Blanc remains illuminated by its direct rays for a much longer time than the surrounding mountains. This phænomenon is owing to the great height of Mont Blanc. But, after it has ceased to be illuminated, the summit of Mont Blanc sometimes reappears at the end of ten or fifteen minutes, less intensely enlightened than at first, but nevertheless in a manner very decided, and often very brilliant. This phænomenon takes place especially when the atmosphere is very pure—highly charged with aqueous vapour in an invisible state—and consequently very transparent. The author has satisfied himself (by the exact observation of the time which elapses between the two successive illuminations of the mountain, combined with the calculation of the sun's progress) that the phænomenon is due to the rays of the sun which traverse the atmosphere at a distance from the earth less than the height of Mont Blanc, but greater than half that height, and which arrive at rarer regions of the atmosphere, under an incidence so great that they are reflected instead of refracted. This interior reflection is facilitated by the humidity of that part of the atmosphere which the rays traverse until they reach the point of incidence. The reflected rays falling on the snowy summit of Mont Blanc, produce this second illumination; and the humidity (by augmenting the transparency of the air) renders the illumination more brilliant.

On the cause of the Optical Phænomena which take place in the Crystalline Lens during the absorption of Distilled Water. By SIR D. BREWSTER, *K.H.*, &c.

Sir David Brewster commenced by drawing the attention of the Section to a representation of the eye of the sheep found among the MSS. of Sir Isaac Newton, in the possession of Lord Portsmouth. The several parts of the drawing under consideration were most carefully laid down on one scale, and the exact measurements given, respecting the cornea in particular. It appeared that it was a portion of an ellipsoid, somewhat longer, but not so deep as the ball of the eye, the cornea being a portion of its most convex part at the major axis. Sir David then went on to introduce the subject of the present communication, by briefly running through the leading points to which he had adverted at the last meeting of the Association, regarding a series of experiments on the crystalline lenses of quadrupeds. From these it appeared that the capsule of the lens absorbs water with great avidity; and during this process exhibits (when exposed to the analysis of polarized light) remarkable changes both in the nature and in the number of the positive and negative doubly refracting structures of which it is composed. These singular, and, in the case of the lens of the horse, very beautiful phænomena, Sir David stated that he was not able to explain when he first made the communication; but he had since returned to the subject, and had succeeded in discovering the cause of the various phænomena which he had observed. While the capsule of the lens is absorbing distilled water, the bulk of the lens is gradually increasing, and consequently the capsule, which he found to be highly elastic, became more and more stretched in the direction of the radii of its circular margin. This extension produces, as may be shown by direct experiment, a negative doubly refracting structure, like the central portion of a positive system of polarized rings, with a rectangular black cross. The tint of this membrane rises to a *white* of the first order; and, as the membrane is double, the two tints will produce, when combined, a *purple* of the first order, which will be the maximum tint developed by the extended capsule just before it bursts. Now it is obvious that the optical figure thus given by the capsule alone will, when combined with the fixed optical figure of the lens itself, produce all the variable phænomena previously observed. If the fixed optical figure consist of two structures, both positive, then one part of the capsule will produce, in the neutral black ring, a negative doubly refracting luminous ring, which separates the two positive luminous rings; while the outer and inner portions of the capsule will act in opposition to the positive structures of the lens, and tend to diminish or obliterate the tints produced at these parts. The result of this combination of actions will be the production of a certain optical figure, in which a negative series of luminous sectors is placed between two positive series of luminous sectors. In the process by which these changes are produced, a new series of luminous sectors, having negative double refraction, has been made to appear in the centre of the

neutral black ring. The inner portion of this black ring has been made to advance inwards, and diminish the size as well as the intensity of the inner or central series of sectors, while the outer portion of the same black ring has encroached in a similar manner upon the outer series of positive sectors, and reduced it both in its size and in the intensity of its illumination. If the original optical figure of the lens consist of one positive structure, or of three structures, the middle one of which is *negative*, and the two others *positive*, the changes which they undergo by the absorption of water, and the consequent extension of the membranous capsule are explicable in the same manner; and not only the character but the numerical value of all the tints which are successively generated can be calculated with the greatest accuracy by assuming a value of the tint produced by each surface of the capsule. In order to remove all ambiguity on the subject, Sir David Brewster extended the capsule of the lens of a sheep over a plate of glass, and by a slight force he readily produced a white of the first order, and of the same numerical value as that which is necessary to produce the phænomena in question. In order to obtain a direct experimental confirmation of these views we have only to take a circular plate of glass which produces, either by rapid cooling, or by the transit of heat, a series of luminous sectors of the same value as that which is produced by the capsule; and, by combining it with the optical figure of the lens, we shall represent all the phænomena exhibited by the lens, when its capsule is expanded by the absorption of water. From the property of the capsule of the lens by which it absorbs water, it is obvious that in certain states of eye it may become so distended with that fluid that it may at length burst, thus giving rise to the disease which has been termed soft cataract; in this case the obvious remedy is to puncture the outer coating of the eye, and thus permit the vicious fluid to escape, and afford a chance to the vessels of resuming their healthy functions. On the other hand, when the defect of the more watery secretions of the eye cuts off the supply, which it would seem that the capsule is intended to furnish to the lens, an opposite course may be requisite, and a supply of water may be injected into the eye; this has actually been done, although when Sir David mentioned the matter in the Medical Section at the last meeting of the Association, Dr. Macartney stated very strongly his doubts of the possibility of such an operation. Thus, it is probable that optical science may have led to an examination of the nature of the membranes of this valuable organ, and most probably that examination will issue in the proper treatment of a most distressing disease, in each of the distinct forms which it is found to assume.

On a new Property of Light. By SIR D. BREWSTER.

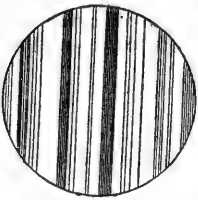
The author observed, that his attention had been lately drawn to a very curious, and new property of light. While examining the solar

spectrum formed in the focus of an achromatic telescope, after the manner of Fraunhofer, he placed a thin plate of glass before his eye, in such a manner as to intercept and retard one half of the pencil, which was entering his eye, by placing it before one half of the pupil. He was then surprised to find, that when the edge of the retarding glass plate was turned towards the red end of the spectrum, intensely black lines made their appearance, as might be expected, at such regular intervals, as to represent the most exact micrometrical arrangement of wires; but upon turning the plate of glass half round, (still keeping its plane perpendicular to the axis of the eye,) so as to present the edge, past which the rays entered the eye, to the violet end of the spectrum, every one of those dark bands entirely disappeared. In the intermediate positions of that edge they appeared more or less distinct, according as the edge was more presented to the red, or to the violet, end of the spectrum. A glass plate, one-thirtieth of an inch thick, gave these lines; but the thinner the glass, the more intense was the blackness, and the more distinct the lines. They were formed in any part of the spectrum; but they were best seen when the rays were intercepted which lay between the two fixed lines A and D of Fraunhofer. An examination of these lines afforded the very best means of determining the dispersive powers of substances; for their distance from one another increases or diminishes, exactly as the entire length of the spectrum is increased or diminished; and the number of them in the same part of two spectra of different lengths is always the same.

Notice of a new Structure in the Diamond. By SIR D. BREWSTER.

Sir David said, that having communicated to the Geological Society an account of certain peculiarities in the structure of the diamond, which confirm the theory of its vegetable origin, he was desirous of submitting to the consideration of this section a new structure, which he had recently detected in that gem, and which indirectly supported the same views. In consequence of the diamond having been used as the fittest substance for forming single microscopes of high power and small spherical aberration, the attention of opticians has been drawn to the imperfections of its structure. Mr. Pritchard, who first succeeded in executing lenses of diamond, put into the hands of Sir David for examination, a plano-convex lens, about the 30th of an inch in diameter, which he had found unfit for the purposes of a microscope, in consequence of its giving double or triple images of minute objects. As Sir David had previously shown that almost all diamonds possessed an imperfect doubly refracting structure, as if they had been aggregated by irregular forces, or compressed or kneaded together like a piece of soft gum or an indurated jelly, he had no doubt that the multiple images were owing to this structure, as there appeared, on an ordinary examination of the lens, to be no other cause to which it could be

reasonably ascribed. This was also Mr. Pritchard's opinion, and the existence of such images prevented opticians from rashly cutting up diamonds which might turn out useless for optical purposes. As lenses of sapphire and ruby, which Sir David had long had occasion to use in very delicate microscopical observations, produced no duplication of the image, although the rays passed in directions in which the double refraction was much greater than in any specimen of diamond which he had examined, it occurred to him that the double images might arise from some other cause. He therefore proceeded to examine the light transmitted through the diamond, by combining it with a concave lens of the same focal length, in order to make the rays pass in parallel directions through its substance. This experiment indicated no peculiarity of structure at all capable of producing a separation of the images, and he was therefore led to examine the plane surface of the lens, by reflecting from it a narrow line of light admitted into a dark room, and examining the surface with a half-inch lens. While turning round the plane surface of the diamond, he was surprised to observe the whole of its surface covered with parallel lines or veins, some of which reflected the light more powerfully than others, so as to have the appearance of a striped riband, somewhat resembling the rude sketch here given, which shows that the plane surface of the diamond,



in a space of less than *one-thirtieth* of an inch, contains many hundred veins or strata of different reflective and refractive powers, as if they had been subjected to variable pressures, or deposited under the influence of forces of aggregation of variable intensity. If, Sir David observed, the planes of these different strata had been perpendicular to the axis of the diamond lens, their difference of refractive power would produce no sensible effect injurious to the perfection of the image; but if these strata are parallel to that axis, as they are in the lens under consideration, each stratum must have a different focus, and consequently produce a series of partially overlapping images.

The results of this experiment in restoring the diamond to its value as an optical material, in so far as it enables us to cut it in a proper direction, and select proper specimens, and its connexion with some delicate researches of Professors Airy and Maccullagh on the superficial action of diamond upon polarized light, possess considerable interest; but the fact of a mineral body consisting of layers of different refractive powers, and consequently different degrees of hardness and specific gravity, is remarkable. There were several minerals, such as *Apophyllite*, *Chabasie*, and others, in which Sir David had found different degrees of extraordinary refraction in different parts of the crystal; but this variation of property depends upon a secondary law of structure; and he believed that there was no crystal, either natural or artificial, in which the properties of ordinary refraction, hardness, and specific gravity, varied throughout its mass. This peculiarity of structure, therefore, might be regarded as an indication of a peculiarity of

origin; and as there are various strong arguments in favour of the opinion that the diamond is a vegetable substance, the new structure which he had described might be considered as an additional argument in favour of that opinion. He had, in a former paper, placed it beyond a doubt, that the diamond must have been in a soft state, like amber or gum, and capable of having its structure modified by the expansive force of air, or gaseous bodies imprisoned in its cavities; and therefore the fact of its being sometimes composed of strata of different degrees of induration and refractive power, was more likely to have been produced by pressures varying during the formation of the crystal, than by any change in the intensity of the forces of aggregation of its molecules. Such a change might have been supposed probable in the diamond had it been previously found in any other crystal. He had already referred to the action which diamond exerts superficially upon light. Professors Airy and Macculłagh have found that this action is of a very peculiar kind, having some analogy with that of metallic surfaces; but it was obvious, from the preceding facts, that a surface of various refractive powers must disturb, in a very considerable degree, the phænomena produced by its superficial action. In studying, indeed, this class of phænomena, it would be necessary not only to obtain a surface of uniform structure, but to make the experiments before that surface had experienced any change from the action of the atmosphere. In surfaces of glass such changes often take place in a few days; and the thin films of oxide which are thus created are so thin that they can only be rendered visible by examining the light reflected from the surface, when it is placed in contact with an *oil* or *liquid* of the same refractive power.

Account of a singular optical Phænomenon, sometimes seen at sunset. By Professor Christie, *Secretary of the Royal Society.*

Mr. Christie drew the attention of the section to an optical phænomenon which he had observed at sunset, when looking from the Down below the Needles Lighthouse, in the isle of Wight, across the Solent, towards the Hampshire coast, and which he had described in a letter to Professor Forbes, referred to in the published Reports of the Association. He stated, that he had observed the same phænomenon on subsequent occasions. The appearance was that of a very distinct vertical ray of yellow light, having the sun for its base, of the same diameter throughout, gradually diminishing in brilliancy, but very distinctly to be traced to the height of more than 30°. This appearance continued for half-an-hour after the sun had set. On two other occasions he had observed what he considered to be the same phænomenon. In one case he happened to be on Westminster Bridge, and on the other on a hill about a mile to the north of the town of Bedford. On both these occasions the sun was considerably above the horizon, perhaps 6° or 7°, the strata of cloud in its vicinity were much denser than on the former ones, and the phænomenon did not present the same marked

character. In these cases, instead of a brilliant ray rising 30° or 40°, the luminous appearance was rather that which would present itself, if a series of images of the sun were superposed, in the line of its vertical diameter, and extending over not more than 4° or 5°; the edges were ill-defined. In his letter to Professor Forbes, Mr. Christie had suggested, whether the phænomenon could be due to a series of reflections of the sun's image by strata of thin cloud; but he now suggested, whether such a phænomenon would not be presented by successive reflections on the undulating surface of a stratum of liquid air, such as M. Poisson, in his new Theory of the constitution of the Atmosphere, has supposed to exist.

On Von Wrede's Explanation of the Absorption of Light, by the undulatory Theory. By* Professor Powell.

Von Wrede supposes the particles of a transparent medium to be placed regularly, at equal distances, (b) so that the æther being diffused among them, the series of waves constituting a ray of light, can be propagated directly through the substance; yet a portion of each wave will encounter some of the particles, and be reflected backwards, and then forwards again, and at length emerge along with the directly transmitted ray, and interfere with it, the conditions of which will depend on the amount of retardation, or differences of the phases; which, if amounting to odd multiples of the half wave-length (λ), will give points of darkness; and if to even multiples, points of brightness. These may be confounded in compound light, but will appear when the rays are separated by the prism, and give dark bands in the spectrum.

He then investigates a formula for the intensity of a system of waves compounded under the conditions supposed. This is deduced from the ordinary formula for the velocity of the wave, and is ultimately brought into a form including certain terms dependent on the medium, and constant for the same medium, together with the factor

$$\cos 2\pi \frac{2b}{\lambda},$$

which is so involved that the intensity is a maximum when the cosine becomes $= +1$, or when $2\pi\frac{2b}{\lambda}$ is an even multiple of a semi-circumference, and a minimum when the cosine $= -1$, or when $2\pi\frac{2b}{\lambda}$ is an odd multiple of a semi-circumference.

Hence if the medium be such that $2b = \frac{\lambda}{2}$ for any primary ray, that ray will be at a minimum, or will appear absorbed. If $2b$ be less than

* See "An Attempt to explain the Absorption of Light according to the Undulatory Theory; by Baron Fabian von Wrede," in Taylor's Foreign Scientific Memoirs, vol. i. p. 477.

the least value of $\frac{\lambda}{2}$, that is, its value for the violet ray, there will be no absorption; if greater, some one ray or more will be at minima. Let us suppose the medium such that $2b = n\lambda$, for any ray. Then, in passing from one end of the spectrum to the other, the changes of intensity and maxima and minima which may occur, will depend on the number of changes which the cosine will go through in passing from its value in the violet ray to that in the red; or, supposing $\lambda_v \lambda_r$ the wave lengths for these rays, from $\cos 2\pi n$ to $\cos 2\pi n \frac{\lambda_v}{\lambda_r}$ through all the intermediate values. The intensity will have as many maxima and minima as the cosine has values $= +1$, and $= -1$. And this number may be increased as much as we please, by supposing (n), or, what is the same thing, (b) taken sufficiently great.

The formula was, in the first instance, deduced for the simpler supposition of a single medium. It is then shown, that if we suppose a compound of several media which have separately different values of b, the resulting formula will still preserve the same condition of depending on the changes of the cosine, and each medium will retain its own set of maxima and minima.

The investigation is conducted in the first instance on the supposition of the internal successive reflexions taking place only between two particles, or sets of particles, or reflecting surfaces. The author next proceeds to the case where more such are taken into account, and deduces a formula more complex, but which results in such a form that the maxima and minima are seen to depend on exactly the same conditions as in the simpler case. In certain cases of the absorption of gases, &c. appearances of a regular and systematical character are presented, and Von Wrede shows that at least a general explanation of all these is afforded by the principles here developed; that is, merely by assigning particular values to b, and supposing those values different in the different simple media of which the compounds are made up.

He also points out one method by which a rough approximation even to a numerical comparison may be effected: it applies very satisfactorily (as far as it goes) to the case of the iodic gas spectrum.

Besides this, the author describes an experiment in which the effect of one or two internal reflexions is imitated by means of plates of mica, and dark bands in consequence produced in the spectrum.

The principles adopted by Von Wrede appear to be quite conformable to what may most reasonably be supposed to take place in the passage of a ray through a transparent body. But so little have the phænomena been reduced to any laws, that we are not yet in a condition to make any satisfactory comparison of observation and theory. The grand object of inquiry must be to obtain, if possible, some numerical laws, expressing the disposition and arrangement of the bands in the spectrum; and in cases where they are apparently destitute of all symmetry, to examine carefully whether any hypothesis of *several sets superposed* will reduce the apparent confusion to order.

Meanwhile, as to the theory, that part of it which refers to the mode of aggregation of the particles of bodies, is necessarily, as yet, hypothetical; and we may therefore still consider as worthy of attention any other principles which may be suggested.

The point on which it is probable any theory must essentially turn is that of a retardation of some part of the light within the medium, and its emerging along with the direct ray in a state of interference.

A ray which enters a medium perpendicularly, though not refracted as to *direction*, is yet *retarded* in proportion to the refractive index for that ray and that medium. Another ray coinciding with it, and having a refractive index slightly different, will be *unequally retarded*; and however small the difference may be, yet in a considerable thickness it may amount to a discordance between the two rays when they emerge; and if their wave lengths differ only by a very small quantity, they may so interfere as to produce a sensible destruction.

If two media are compounded together which have the same refractive index for one ray, and different indices for a ray whose wave length differs very little from the first, that which retards it most will prevail, and the two rays may interfere and produce darkness from this cause.

But the recent theoretical researches of Professor Lloyd, communicated to the Royal Irish Academy, seem to promise an explanation of the absorption, and with views somewhat different, connected with his profound investigations on the propagation of light, and dependent on the mathematical form which the expressions assume under certain conditions. This was also, to a certain extent, a consequence from some of the analytical investigations of Mr. Tovey on the dispersion.

On the Dispersion of Light. By PROFESSOR POWELL.

The object of this communication is to state the progress of the inquiry into the subject of dispersion since the last meeting of the Association. On that occasion the author laid before the physical section the results of his observations for determining the refractive indices of the standard rays for twenty-eight media. These have been since published, with some preliminary remarks, as one of the series of Memoirs of the Oxford Ashmolean Society. They are to be considered only as first approximations, and it would be very desirable to have many of them carefully repeated, as well as to extend the inquiry to other bodies. The author regrets that he has been unable, from particular circumstances, to carry on these researches during the past summer, but intends to take the first opportunity of resuming them. In particular, he was kindly favoured by Mr. Brooke with a specimen of some crystals of chromate of lead for examination, and accordingly put them into the hands of Mr. Dollond, who warmly entered into his views, and after many vain endeavours to give them a prismatic form, has at length succeeded in forming a very minute prism which is under trial.

It is only by such cooperation of those engaged in different departments of science that inquiries like the present can be successfully carried on, and the author is anxious to obtain specimens of any transparent media which are capable of prismatic examination, and especially such as are of high dispersive power.

Meanwhile he has been engaged in the comparison of observation and theory; especially among the more highly dispersive of those media which he has examined. He has performed the calculations by the method of Sir W. R. Hamilton, and has found that for those media whose dispersion is not very great, the coincidences are sufficiently close; but on proceeding to the more highly dispersive bodies, especially oil of cassia, the discrepancies increase; and, moreover, preserve a certain regularity of character which shows that they are not mere errors of observation. This would seem to warrant the expectation, that a further development of the formula might still give successful results. These investigations have been communicated to the Royal Society, and have now appeared in the Transactions.

Since the period of this communication, however, the able and profound Memoir of Mr. Kelland appeared in the Cambridge Transactions. This gentleman's theory is, in some measure, a simplification of Cauchy's; the resulting formula for the dispersion, though substantially the same, is developed in a different form, and readily capable of being applied to numerical computation. In some correspondence with Mr. Kelland, that gentleman favoured the author with a computation for the case of oil of cassia, in which the greatest discrepancies existed. By this method those discrepancies have been made entirely to disappear; and thus the most *extreme case* at present known is brought under the dominion of the formula of dispersion. It is also to be observed that Mr. Kelland's series is not rapidly converging; the neglected terms therefore *may*, if taken into account, give a still more accurate result. These results will appear in the Philosophical Transactions.

It will now, therefore, become of yet more extreme interest to find some means of obtaining data for the more highly dispersive substances, such as chromate of lead, realgar, sulphur, &c.

With regard to the theoretical computation, it must be owned, after all, that it is not altogether satisfactory in its nature, as it assumes three indices from observation, and thence determines the others, which is in fact a process of interpolation, and does not explain the character of the dispersion as referring to those three indices. Whether the theory can be improved in this respect becomes an important topic of inquiry.

But the whole subject has now been most ably examined by Professor Lloyd, whose papers have been communicated to the Royal Irish Academy, and include several highly curious and important theoretical conclusions relating to the whole subject of the propagation of light in uncrystallized media.

On Experiments relative to the influence of Surfaces on Radiation. By Professor Powell.

The object of this communication was to call the attention of the Section to the researches of Professor Bache, of Pennsylvania, which seem not to have been so fully appreciated in this country as they deserve; that gentleman, at the outset of his inquiries, refers to a paper of Professor Powell, in which the difficulties unavoidably attending any comparison of radiating effects of surfaces are pointed out, from the impossibility of determining precisely in how many other respects, besides those of colour and polish of surface, the coatings applied may not differ. In contending for the necessity of *equalizing* the coatings compared in other respects, before we can estimate the effects really due to the *surface*, he must of course be understood to speak under the qualification acutely referred to by Professor Bache dependent on the fact first noticed by Leslie, that radiation takes place not only from the surface, but from a certain minute though sensible depth, which differs in different substances. Taking this into account, the general meaning as well as importance of the caution will be manifest. In the sequel Mr. Bache gives some very exact experimental proofs of the truth of the law just noticed, and shows, by successively adding fresh coats of the pigment, the precise limit beyond which such addition ceases to increase the radiating power; which, in fact, there comes to a maximum, and with greater thicknesses decreases. When this point had been carefully ascertained in each pigment, their effects were observed with great accuracy, and compared with a standard surface under similar circumstances. The observations include a considerable range of substances, differing both in colour and other properties. The results exhibit *no correspondence of the greatness of effect with the colour.* The source of heat was hot water. The author allows fully the distinction between properties of heat of this kind, and that connected with light; in the latter case it is evident that colour is an essential element. A wide field is yet open for tracing on what the effect *does* depend; and, again, since Melloni has pointed out the existence of many kinds of heating rays, to trace their several relations to *surfaces.*

An Account of the Magnetical Observatory now in course of erection at Dublin. By Rev. Professor Lloyd.

In bringing this subject under the notice of the Section in its present stage, Mr. Lloyd said that he trusted little apology was required. The establishment of permanent magnetical stations had been urged by the powerful recommendation of the British Association; and he was sure that that body would view with interest the progress of an undertaking, which was sanctioned by its own authority.

The magnetical observatory now in progress at Dublin is situated in an open space in the gardens of Trinity College, sufficiently re-

mote from all disturbing influences. The building is forty feet in length by thirty in depth. It is constructed of the dark-coloured argillaceous limestone, which abounds in the valley of Dublin, and which has been ascertained to be perfectly devoid of any influence on the needle. This is faced with Portland stone; and within, the walls are to be *studded,* to protect from cold and damp. No iron whatever will be used throughout the building. With reference to the materials, Professor Lloyd mentioned, that in the course of the arrangements now making for the erection of a Magnetical Observatory at Greenwich, Mr. Airy had rejected bricks in the construction of the building, finding that they were in all cases magnetic, and sometimes even polar. Mr. Lloyd has since confirmed this observation, by the examination of specimens of bricks from various localities; and though there appeared to be great diversity in the amount of their action on the needle, he met with none entirely free from such influence.

The building consists of one principal room, and two smaller rooms, one of which serves as a vestibule. The principal room is thirty-six feet in length by sixteen in breadth, and has projections in its longer sides, which increase the breadth of the central part to twenty feet. This room will contain four principal instruments, suitably supported on stone pillars; viz. a transit instrument, a theodolite, a variation instrument, and a dip apparatus. The transit instrument (four feet in focal length,) will be stationed close to the southern window of the room. In this position it will serve for the determination of the time; and a small trap-door in the roof will enable the observer to adjust it to the meridian. The theodolite will be situated towards the other end of the room, and its centre will be on the meridian line of the transit. The limb of the theodolite is twelve inches in diameter, and is read off by three verniers to ten seconds. Its telescope has a focal length of eighteen inches, and is furnished with a micrometer for the purpose of observing the *diurnal variation.*

The variation instrument will be placed in the magnetic meridian, with respect to the theodolite, the distance between these instruments being about five feet. The needle is a rectangular bar, twelve inches long, suspended by parallel silk fibres, and inclosed in a box to protect it from the agitation of the air. The magnetic bar is furnished with an achromatic lens at one end, and a cross of wires at the other, after the principle of the collimator. This will be observed with the telescope of the theodolite, in the usual manner; and the deviation of the line of collimation of the collimator from the magnetic axis will be ascertained by reversal. The direction of the *magnetic* meridian being thus found, that of the true meridian will be given by the transit. It is only necessary to turn over the transit telescope, and, using it also as a collimator, to make a similar reading of its central wire, by the telescope of the theodolite. The angle read off on the limb of the theodolite is obviously the supplement of the variation. This use of the transit has been suggested by Dr. Robinson; and it is anticipated that much advantage will result from the circumstance, that the two extremities of the arc are observed by precisely the same instrumental

means. With this apparatus it is intended to make observations of the *absolute variation* twice each day, as is done in the observatory of Professor Gauss, of Göttingen,—the course of the *diurnal variation*, and the hours of maxima and minima, having been ascertained by a series of preliminary observations with the same instrument. A similar instrument, in a form somewhat modified, will serve for the observation of the diurnal changes of the horizontal force.

An apparatus, constructed by M. Gambey, and similar to the one made by that artist for M. Kupffer, will be used in observing the diurnal variations of the dip. Gauss's large apparatus will also be set up in the same room, and will be used occasionally, especially in observations of the *absolute intensity*, made according to the method proposed by that distinguished philosopher. The bars are too large to be employed in conjunction with other magnetical apparatus.

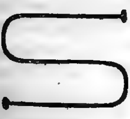
It is intended to combine a regular series of meteorological observations, with those on the direction and intensity of the terrestrial magnetic force just spoken of; and every care and precaution has been adopted in the construction of the instruments.

In conclusion, Mr. Lloyd said, that he felt it a duty to allude to the liberality and zeal in the cause of science which had been evinced by the Board of Trinity College on this occasion. The probable expense of the building and instruments is estimated at 1000*l.*; and that sum was immediately allocated to the purpose, when it appeared that the interests of science were likely to be benefited by the outlay.

Notice of Electrical Researches by PROFESSOR HENRY, *of Princeton, U.S.*

The primary object of these investigations was to detect, if possible, an inductive action in common electricity, analogous to that discovered in a current of galvanism. For this purpose an analysis was instituted of the phænomena known in ordinary electricity by the name of the lateral discharge. Professor Henry was induced to commence with this from some remarks by Dr. Roget on the subject. The method of studying the lateral spark consisted in catching it on the knob of a small Leyden phial, and presenting this to an electrometer. The result of the analysis was in accordance with an opinion of Biot,—that the lateral discharge is due only to the escape of the small quantity of redundant electricity which always exists on one or the other side of a jar, and not to the whole discharge. The Professor then stated several consequences which would flow from this; namely, that we could increase or diminish the lateral action, by the several means which would affect the quantity of redundant, or, as it may be called, free electricity, such as an increase of the thickness of the glass, or by substituting for the small knob of the jar a large ball. But the arrangement which produces the greatest effect, is that of a long fine copper wire insulated, parallel to the horizon, and terminated at each end by a small ball. When sparks are thrown on this from a globe of about a foot in diameter, the wire, at each discharge, becomes

beautifully luminous from one end to the other, even if it be a hundred feet long: rays are given off on all sides perpendicular to the axis of the wire. In this arrangement the electricity of the globe may be considered nearly all as free electricity; and as the insulated wire contains its natural quantity, the whole spark is thrown off in the form of a lateral discharge. But to explain these phænomena more fully, Professor Henry remarked, that it appeared necessary to add an additional postulate to our theory of the principle of electricity,—namely, a kind of momentum, or inertia, without weight; by this he would only be understood to express the classification or generalization of a number of facts, which would otherwise be insulated. To illustrate this, he stated that the same quantity of electricity could be made to remain on the wire if gradually communicated; but when thrown on in the form of a spark, it is dissipated as before described. Other facts of the same kind were mentioned; and, also, that we could take advantage of the principle to procure a greater effect in the decomposition of water by ordinary electricity. The fact of a wire becoming luminous by a spark was noticed by the celebrated Van Marum more than fifty years ago; but he ascribed it to the immense power of the great Haarlem machine. The effect, however, can be produced, as before described, by a cylinder of Nairn's construction, of seven inches in diameter, a globe of a foot in diameter being placed in connexion with the prime conductor to increase its capacity.



Some experiments were next described, in reference to the induction of the lateral action of different discharges on each other. When the long wire is arranged in two parallel, but continuous lines, by bending the wire, the outer side of each wire only becomes luminous; when formed into three parallel lines by a double bend, the middle portion of the wire does not become luminous, the outer sides only of the outer lines of wire exhibit the rays. When the wire is formed into a flat spiral, the outer spiral alone exhibits the lateral discharge, but the light in this case is very brilliant; the inner spirals appear to increase the effect by induction.

Professor Henry stated, that a metallic conductor, intimately connected with the earth at one end, does not silently conduct the electricity thrown in sparks on the other end. In one experiment described, a copper-wire, one-eighth of an inch in diameter, was plunged at its lower end into the water of a deep well, so as to form as perfect a connexion with the earth as possible; a small ball being attached to the upper end, and sparks passed on to this from the globe before mentioned, a lateral spark could be drawn from any part of the wire, and a pistol of Volta fired, even near the surface of the water. This effect was rendered still more striking, by attaching a ball to the middle of the perpendicular part of a lightning rod, put up according to the directions given by Gay-Lussac; when sparks of about an inch and a half in length were thrown on the ball, corresponding lateral sparks could be drawn not only from the parts of the

rod between the ground and the ball, but from the part above, even to the top of the rod. Some remarks were then made on the theory of thunder-storms, as given by the French writers, in which the cloud is considered as analogous in action to one coating of a charged glass, the earth the other coating, and the air between as the non-conducting glass. One very material circumstance has been overlooked in this theory,—namely, the great thickness of the intervening stratum, and the consequent great quantity of free or redundant electricity in the cloud. This must modify the nature of the discharge from the thunder-cloud, and lead to doubt if it be perfectly analogous to the discharge from an ordinary Leyden jar, since the great quantity of redundant electricity must produce a comparatively greater lateral action; and hence, possibly, the ramifications of the flash and other similar phænomena may be but cases of the lateral discharge.

Some facts were then mentioned, on the phænomena of the spark from a long wire charged with common or atmospheric electricity. It is well known that the spark in this case is very pungent, resembling a shock from a Leyden jar. The effect does not appear to be produced, as is generally supposed, by the high intensity of the electricity at the ends of the wire by mere distribution, since this is incompatible with the shortness of the spark. In one experiment, fifteen persons, joining hands, received a severe shock, while standing on the grass, from a long wire,—one of the number only touched the conductor; the spark in this case was not more than a quarter of an inch long. Several other analogous facts were mentioned, and the suggestion made, that the whole were probably the result of an inductive action in the long wire, similar to that observed in a long galvanic current: the subject now required further investigation.

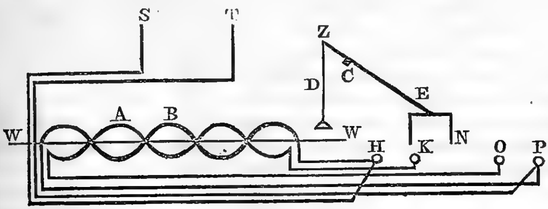
Professor Henry concluded by observing, that the facts he had given in this communication were such as must have been noticed by every person who is in the habit of experimenting on ordinary electricity; but he believed these had never been studied in this connexion. He was anxious to direct the attention of the Section to the subject, as one which appeared to afford an interesting field of research, particularly in connexion with the recent discoveries of the surprising inductive actions of galvanic currents.

On a convenient and efficient form of Electro-magnetic Apparatus for the production of Electricity of high Intensity. By Rev. J. W. M'Gauley, *Professor of Natural Philosophy to the National Board of Education in Ireland.*

He remarked that, although he had not altered his opinions on the applicability of Electro-magnetism as a moving power, he conceived we ought not to be satisfied with almost any portion of our present electro-magnetic apparatus; but that all that an individual

could, *unassisted*, hope to achieve, would be to simplify and improve singly its various portions.

Any one, he observed, who had experimented on a large scale, must have found that the galvanic apparatus becomes considerable in size, and troublesome in operation; he had determined, therefore, to devote some time to the construction of a machine, from which we might obtain electricity of very high intensity, to be applied, if possible, to the magnetization of bars of soft iron. He was aware that a considerable effect was said to have been produced by a battery consisting merely of a wire of zinc, and another of platina, and a small quantity of acid; but as there is no standard for the measure of physiological effects but the variable susceptibility of individuals, he could not but think, from a variety of experiments he had made, that the shock was magnified by the surprise of the experimentalist, as we know it to have been at the discovery of the principle of the Leyden jar: of the power of the apparatus before it the Section could judge for itself. Its construction was simple and permanent; and, from the ease with which it could be applied, and the power we possess of diminishing, at pleasure, the number and intensity of the shocks, it appeared well calculated for the purposes of medical electricity. It is self-acting; and as it requires no aid from the operator for the production of continued electrical effects, when once excited, it leaves his attention undivided for experiment. Besides the arrangement of its parts, which he believed to be the best of any he had tried, and which he would detail to the Section, he was inclined to attribute its efficiency to a number of circumstances he had not yet sufficient time to develope, and whose consideration, therefore, he would leave to another opportunity.



W W is a bar of soft iron 2 feet long, 3-4ths of an inch in diameter. A and B two helices, each about 580 feet long, No. 13 copper wire, one dextrorsum, the other sinistrorsum; the coils of each are superimposed alternately on the other. H and P are mercury cups, connected with cylinders of copper S and T, for giving the shock, and with the extremities of helix B. K and O mercury cups, connected with helix A. N, and the same cup O, connected with the poles of a small calorimeter; D a copper wire, carrying a soft iron knob to be attracted by the bar W W, and, when attracted, to draw down the lever Z E, turning on the centre C, and having fixed on its longer arm the curved wire E, which, being elevated or depressed, makes

or breaks battery connexion with the extremities of helix A. The helices, bar, and wires, are enclosed, permanently, in a strong deal case, upon which are screwed the copper cylinders S and T, the fulcrum C upon which Z E moves, and the cups of mercury H, K, N, O, P. By sliding a small wedge under the extremity of the lever E, the knob D more nearly approaches the bar W W, and being more easily, is, therefore, with greater frequency attracted by it, as the time necessary for intense magnetization is not then required; a spring also sliding under E lightens the latter, and without bringing the knob nearer to W W, renders its attraction more easy: both wedge and spring will be found useful.

Since battery connexion is broken by the apparatus itself, and at the moment the magnetism and excitement of the helix have reached their highest intensity, the circumstances are, in consequence, most favourable for the production of the desired effect; hence, to break connexion more rapidly, either by a separate mechanism, or by regulating the wedge and spring of the apparatus itself, though it increase the number, cannot augment the violence of the shocks. This was shown by experiment; and it was said to be in accordance with the belief of Dr. Faraday, who says, (Phil. Trans. 1832,) "that a magnet, even of soft iron, does not arrive at its fullest intensity in an instant." The mercury cups are arranged so that the experimenter may connect the extremities of the helices, the cylinders, and the battery, as he pleases. That contact, when broken, may be broken with great rapidity, the wire E is attached to the longer arm of the lever.

It is said, Mr. M'Gauley continued, that mere metallic contact, without mercury cups, is sufficient, and he hoped it was so; but he had reason, from experiment, to fear, that a pressure of the metals, incompatible with the delicate action of the machine, would be required. Besides many, and he was induced to hope important differences between this and other contrivances, he thought it right to remark, in anticipation of what perhaps might be said, that the coils used by Dr. Faraday and Professor Jacobi were not the same as the present; and the importance even of the manner of *coiling* the wire, may be inferred from the fact, that out of four arrangements, the same in every respect except the coiling of the wire, none was at all comparable in effect with the one exhibited. Dr. Faraday's coils, as they were nearly of the same length,—(paper read before the Royal Society, Jan. 29, 1835: *Athenæum*, No. 391)—must have been placed beside each other in the same stratum on the bar; and Jacobi (Scientific Memoirs, part 4) coiled the wires together in *one helix*.

That the action of the apparatus was very great, was, he observed, manifest to all present; and he had not known any person, when it was in order, as it then was, able to retain the hands, wetted with water, on the cylinders for an instant; nor, very frequently, the hands even unwetted. With this apparatus we have a very convenient means of trying the beautiful experiment of Dr. Faraday, repeated by Jacobi. They found that when two wires were coiled in a parallel direction, and the extremities of one of them united, the spark and shock were

diminished or destroyed; in addition, we find the magnetizing power of the battery lessened, or altogether interrupted, for the bar W W is no longer able to attract E as before. Dr. Faraday had ascribed the disappearance of the secondary current to the production of a current in the parallel wire, which current, had that wire not been present, or had its extremities not been united, would have been found in the conducting wire itself; and he supposes the parallelism of the wires to be necessary in the arrangement, yet, in the present case, the wires are not parallel, though the effects remain unchanged. It is possible to unite the extremities of helix B with the helix of an electro-magnet in such a manner as to excite the latter. When the apparatus is made to act so weakly as that the hands may be retained on the cylinders for a number of rapidly succeeding shocks, it is sometimes very difficult to disengage them. He was induced to believe that increasing the number of galvanic circles, without diminishing the size of plates, would increase the effect. He found it more useful to increase the energy of the battery by strengthening the acid mixture, than by enlarging the plates. When too powerful a battery is used, rendering the contact between some of the connecting wires less perfect, made the machine uniform in its action. Jacobi says that, in his experiment, increasing the battery did not increase the effect; but Mr. M'Gauley showed the contrary, by experiment, in this case. Still, whatever was the reason, he observed, he did not, even in an arrangement similar to that of Professor Jacobi, find that a very small battery produced an effect equal to that of a larger one: so much do circumstances, unnoticed or unappreciated, sometimes alter, not only the extent, but the nature of results.

On the Interference of Electro-magnetic Currents. *By* M. De la Rive.

After a brief *résumé* of the known properties of electro-magnetic currents, M. De la Rive adverted to some new results at which he had arrived in studying them. He remarked, that in chemical decomposition effected by these currents, the *individual* force of each was greater the more rapidly they succeeded each other; so that, to decompose a given quantity of water, it becomes necessary to have a number of these currents, so much the greater as the succession is less rapid. There is, however, a limit beyond which the force of the currents is not augmented by any further augmentation of the rapidity of the succession. When plates of platina are employed, instead of wires, in the decomposition of water, the decomposition ceases to take place when the surface of contact of the metal with the liquid surpasses a certain limit. Nevertheless, the current, far from diminishing in intensity, becomes, on the contrary, more intense—as is shown by the indications of a metallic thermometer—the helix of which, placed in the current, furnishes a measure of its calorific energy. As

soon as the surfaces of contact are of such magnitude that decomposition is no longer effected, the thermometer reaches a maximum, which it does not pass, even when the surfaces of contact are augmented. This fact seems to prove, that chemical decomposition produced by electrical currents takes place only when these currents undergo a certain resistance in their passage from the metal into the liquid; and that, when this resistance does not exist, decomposition ceases. When we employ wires of platina to transmit the magneto-electric currents into a solution of any kind, whether acid, saline, or alkaline, we, at first, observe an abundant evolution of gas; then this disengagement diminishes, and at the end of fifteen or twenty minutes it altogether disappears. When we examine these metallic wires, we find them covered with a very fine powder, composed of platina in the metallic state, but extremely divided. The same phænomenon takes place with gold, palladium, silver, &c. All these metals are covered, in the same manner, with a very fine coating of the metal itself, in a state of extreme subdivision. The author has assured himself that this powder is composed of the metal itself, and not an oxide or a suboxide. He inquired whether this effect is the result of the mechanical shocks that the molecules of the metal undergo by the action of these currents, which are discontinuous, and alternately in opposite directions; and whether it would not be augmented by the succession of oxidations and deoxidations, which would occur on the surface of the wires. He concluded by stating, that he had observed that the armatures of soft iron, (about which the metallic wires are coiled, in which the currents are developed by induction,) cease to be attracted by the poles of the magnets, before which they pass when the two ends of the wire in which the current is developed are united by one good metallic conductor; a fact which would seem to prove that Magnetism and Dynamical Electricity are, in these cases, but two different forms of the same force, one of which disappears when the other becomes apparent; and he insisted on the advantage that we might derive from this property in the production of motion by electro-magnets.

On the two Electricities, and on Professor Wheatstone's Determination of the Velocity of Electric Light. By W. Ettrick.

On the occurrence of the Aurora Borealis in England during summer; with a recommendation that the phænomenon should, at all seasons, be more carefully observed than hitherto. By S. Hunter Christie, *M.A., Sec. R.S., &c.*

The occurrence of an Aurora borealis in the very middle of summer is a phænomenon hitherto unrecorded, and as no account, that I am aware of, has appeared of a very brilliant Aurora which was exhibited

and which I observed on the 24th of June of the present year, I consider that a notice of such an occurrence cannot but be interesting to the Section.

The phænomenon, on this occasion, presented the usual appearances, although the coruscations were not of that vivid and brilliant character which they have frequently presented during the darker nights of the winter and spring of the present year. The streamers were bright, but more steady than are sometimes observed, and occasionally rose to the height of 50° above the northern horizon. No arch was observed, but the usual darkness, which I should hesitate to designate as cloud, was early observed in the northern horizon, though this was at no time so well defined as I have on many occasions seen it. The aurora was first observed at $11^h\ 46^m$ p.m., and continued until $12^h\ 20^m$, the streamers extended over a space of 20°, the magnetic north being its middle point.

This is not by any means a solitary instance of the occurrence of Aurora during the last summer.

On the 19th May I observed a very fine Aurora. On this occasion, two very beautiful bands of arches, radiating from magnetic west, extended nearly to the opposite horizon. One, when first observed, extended directly over head, was very thin and not very perceptible in the east; the other, a much narrower band, consisting of three or four arches, not defined with the same distinctness throughout, rose to the height of 40°, and extended to the opposite horizon. The arches had a slow motion from north to south (magnetic), and in their course passed over several stars, and also the planet Jupiter, and the brilliancy of these was but slightly dimmed by the interposition of the arch. No streamers were seen on this occasion, nor did I note the appearance of the usual darkness in the northern horizon. The arches were observed from $9^h\ 40^m$ till $10^h\ 15^m$. The moon was near the full, which rendered the phænomenon less striking than it otherwise would have been.

On the 1st July, at $12^h\ 30^m$, I observed indications of an Aurora about the magnetic north. I noticed a faint coloured light above two, not very well defined, bands of darkness. At $1^h\ 10^m$ I was called up to witness a vivid and brilliant display of coruscations. These rose, to the height of 30° or 40°, over an extent of more than 20°, from the dark cloud usually attending the Aurora. Although they were most brilliant when first observed, beams of light were visible for a quarter of an hour; but after this, if any coruscations occurred, they were invisible, in consequence of the increasing light from the sun. No arches were, on this occasion, observed. On the 2nd July there were decided appearances of Aurora, accompanied by streamers; but these were much fainter than on the preceding night; and, again, on the 7th there were indications of Aurora, though of a less decided character.

On the 25th August there was a very splendid display of Aurora, which continued from $10^h\ 25^m$ until $10^h\ 51^m$. The streams of light were extremely brilliant, and rose to a considerable height, passing,

in some instances, over stars of the first magnitude, whose lustre was but little diminished by their light.

On this occasion I noticed a phænomenon which I had some years before observed in a most striking form: namely, the dark Aurora cloud breaking through the light above it. Having, on the former occasion to which I have just alluded, omitted to note the month and year, at the time I noted the successive appearances of the Aurora, I cannot now refer to the date. I first observed the Aurora at $7^h\ 30^m$, in the form of a faint arch, about 25° in height, its middle point bearing nearly magnetic north. This arch continued for nearly two hours, becoming gradually brighter. It was succeeded by three arches, formed one within another, and having, 10° below them, a dark arch. These again were, in about an hour from their first appearance, succeeded by a single well-defined arch, in the same position, and having below it a remarkably well-defined dark arch. This shortly afterwards appeared to break through the luminous band, dark streams rushing upwards, and breaking up the arch in every part: these dark streams were almost immediately succeeded by brilliant coruscations. Subsequently, both the dark arch and luminous band were re-formed. Captain Back has since observed a similar phænomenon, in a still more striking form, while in his winter quarters at Fort Reliance.

I have on other occasions, during the present summer, observed clear indications of Aurora, though not of a decided character; but these are sufficient to show that this phænomenon occurs at all seasons of the year, and to render it probable that it is principally the shorter duration of the nights from the vernal to the autumnal equinox which renders it less frequently visible during this period than in the winter half of the year. I have here only noticed the occurrence of the Aurora during the summer; but all must be aware how frequently, and with what brilliancy, it has presented itself in the south of England during the last twelve months; indeed, I consider, that in no case has a period of a month elapsed without a striking exhibition of it. In the month of February there occurred one, the most extraordinary that, I believe, is on record in these latitudes.

To what are we to attribute this frequent occurrence, during the present and a few previous years, of a phænomenon which had for a considerable time before been comparatively rare?* This is an important question in meteorology, to which, in the present state of science, only conjecture can be offered in reply; and this must continue to be the case, until the phænomenon itself, with all its attendant circumstances, shall have been more carefully observed than hitherto. My own avocations are of a nature to preclude me from making such observations; but I entertain a confident hope, that there will not be wanting members of the British Association both willing and able to devote their time and attention to this highly interesting inquiry.

* May 30, 1838. I may now remark that, as far as my own observation and any information I have obtained go, the Aurora Borealis has been of very rare occurrence, in the south of England, during the last winter and the present spring, particularly as compared with the preceding year. This is the more remarkable when taken in conjunction with the severity and long continuance of the cold weather.—S. H. C.

It may be superfluous to point out, to persons disposed carefully to observe this phænomenon, the necessity of watching for every indication of its appearance—the low dark arch in the north, for example, one of the most infallible—or the importance of noting, as accurately as possible, the time, bearing, and altitude of each particular appearance; but I would especially call their attention to every circumstance connected with the dark arch; the first indications of its formation; the manner in which it occasionally breaks up; whether irregularities in its form are always attended with coruscations; whether, as it has appeared to me, the matter of which it is composed does commonly rush through the luminous bands; whether, in short, all the phænomena will warrant the conclusion, that the matter which, during an Aurora, appears in the form of a dark low arch, is different from that forming the luminous bands, and that the different phænomena are due to the action of the same cause, on two aeriform masses, which have distinctive characters with reference to such action.

METEOROLOGY, &c.

On M. Poisson's Theory of the Constitution of the Atmosphere. By J. W. Lubbock, *F.R.S., &c.*

He commenced by observing, that at a late meeting of the Section,* M. De la Rive described a very curious phænomenon presented by Mont Blanc after sunset, which consisted in the *re-appearance* of the red colour of the snow, produced by the rays of the setting sun. Mr. Lubbock said that he should now venture, with great diffidence, to submit the possibility of the following explanation.

M. Poisson considers it a necessary consequence of the laws of equilibrium of elastic fluids, that the atmosphere of the earth, at a certain height, becomes liquefied by cold.—(Traité de Mécanique, vol. ii. p. 612;† Théorie Mathématique de la Chaleur, p. 460, et Supplement, note D.)—In this way the atmosphere receives an abrupt termination, without which, indeed, it would be difficult to imagine that the planets and comets move in space devoid of considerable resistance. If the atmosphere be constituted as M. Poisson infers from analysis, it seems to me, Mr. Lubbock observed, that we might expect that the phænomenon described by M. De la Rive would take place, and that the image of the sun, reflected from the interior surface of the *liquid air*, would be reflected again to the observer, after *sunset*, by the mountain. On the other hand, it may be stated, that an observer stationed, at sunrise or sunset, upon Mont Blanc, or in a balloon, or in any position sufficiently elevated, ought to see in the sky the reflected image of the sun; and that there is no observation of this

* See p. 10 of these Transactions.

† " Ainsi, pour fixer les idées, on peut se représenter une colonne atmosphérique qui s'appuie sur la mer, par exemple, comme un fluide élastique terminé par deux liquides, dont l'un a une densité et une température ordinaire, et l'autre une température et une densité excessivement faibles."

kind upon record. If, however, this phænomenon were to take place, it might not be referred by the observer to the proper cause. A terrestrial object seen by reflection in this manner would be reversed; but it is, perhaps, not impossible, that although the internal surface of the liquid air might not reflect mountains in this manner, it might reflect so bright an object as the sun. Halos might, perhaps, always be produced by transmitted light. It might also be remarked, that the liquid heterogeneous thickness of air opposes a difficulty to the calculation of astronomical horizontal refractions by the method of mechanical quadratures, devised by the late Mr. Atkinson, and employed by him in the Transactions of the Astronomical Society, and by M. Biot in the Conn. des Temps, unless somewhat modified.

On the Principle of Mr. Whewell's *Anemometer.*

The author rapidly sketched the principle on which his instrument registered the quantity of aërial current passing any place. He had exhibited the instrument in an unfinished state at the Dublin meeting, and in a more matured state of its existence at Bristol; it had since received some valuable improvements, which were suggested by the practical working of the machine. That he might not occupy the time of the Section too long, it would suffice at present to say, that in it a small set of windmill vanes, something like the ventilators placed in our windows, were presented to the wind by a common vane, let the direction of the wind blow how it might: the aërial current as it passed set these vanes into rapid motion, and a train of wheels and pinions reduced the motion, which was thence communicated to a pencil traversing vertically, and pressing against an upright cylinder, which formed the support of the instrument, and that 10,000 revolutions of the fly only caused the pencil to descend the one-twentieth of an inch. The surface of the cylinder was japanned white, and the pencil as the vane wavered kept tracing a thick irregular line, like the shadings on the coast of a map: the middle of a line was readily ascertained, and it gave the mean direction of the wind actually exhibited before the eye by a diagram, while the length of the line was proportional to the velocity of the wind, and the length of time during which it blew in each direction; which therefore gave what he called the integral effects of the wind, or the total amount of the aërial current which had passed the place of observation in the direction of each point of the compass, during the interval which had elapsed since the time of last recording the instrument. This, it was well known, was a subject of much importance in meteorological speculations, but had not been hitherto accomplished. It was indeed deemed of much consequence to obtain even the mean direction of the wind at a given place, and the celebrated Kämtz, in his *Meteorologie,* has made a collection of several results of this kind; but, in the ordinary way of registering even the direction of the wind, which is by stating

the length of time it blows from a certain point of the compass, it is obvious that the velocity of the wind is altogether left out of account, and the high wind or storm of one day is placed on a par with the gentle breeze of the next, and therefore not an attempt can be made to infer the total quantity, or what he had ventured to term the integral effect of the wind. Mr. Whewell then proceeded to exhibit large diagrams, giving the results of the observations recorded at the Cambridge observatory, under the care of Professor Challis, and at the house of the Cambridge Philosophical Society. The similarity of the curves showed a general coincidence, but some discrepancies were accounted for by the circumstance, that the dome of the Equatorial sheltered the anemometers placed at the observatory on the north side, while that placed upon the house of the Philosophical Society was well situated for receiving the wind from every quarter. Anemometers on this principle had been also erected by Professor Forbes and Mr. Rankin, at Edinburgh, and by Mr. Snow Harris and Mr. Southwood at Plymouth; but he was not at present prepared to state the results of these observations, though he had little doubt they would be interesting and useful.

An Account of his Observations with Mr. Whewell's *Anemometer. By Mr.* Southwood.

Mr. Southwood noticed some imperfections in the original construction of the instrument, which only forced themselves upon his attention as the evils which arose from them became obvious in the practical working of the machine. He pointed out the remedies which he had adopted. The most important were, the use of the successive letters of the alphabet, A, B, C, &c. to mark the successive points to which the wind shifted in the register;—a ready means of unclamping the nut carrying the pencil, (which descends 1-20th of an inch for ten thousand revolutions of the fly,) as soon as it has reached the bottom, and replacing it at the top;—also ready means of placing a new fly on the axle when any accident occurred to the one which had been there;—a means of protecting the parts most liable to injury from wet; —and various other points, which his attention to the performance of the machine had made him perceive the importance of.

An Account of a New Registering Anemometer and Rain-Gauge, now at work at the Philosophical Institution at Birmingham, with diagrams giving a condensed View of the Observations recorded during the first eight months of the year 1837. *By* Follett Osler, *of Birmingham.*

Having about eighteen months ago constructed an instrument to register the variations in the direction and force of the wind, as well as the quantity of rain that falls, which instrument has been in constant operation since November last, the author was induced, at the request of several scientific members of the Association, to lay before the Meet-

ing an account of these instruments, together with some tables, founded on the records they have furnished. He also presented drawings of the Registering Anemometer and Rain-Gauge alluded to.

The direction of the wind is obtained by means of the vane attached to the rod, or rather tube, that carries it, and consequently causes the latter to move with itself. At the lower extremity of this tube is a small pinion working in a rack, which slides backwards and forwards as the wind moves the vane, and to this rack a pencil is attached, which marks the direction of the wind on a paper ruled with the cardinal points, and so adjusted as to progress at the rate of one inch per hour by means of a clock; the force is at the same time ascertained by a plate one foot square, placed at right angles to the vane, supported by two light bars running on friction rollers, and communicating with a spiral spring in such a way that the plate cannot be affected by the wind's pressure without instantly acting on this spring, and communicating the quantum of its action by a light wire passing down the centre of the tube to another pencil below, which thus registers its degree of force. The rain is registered at the same time by its weight acting on a balance which moves in proportion to the quantity falling, and has also a pencil attached to it recording the results. The receiver is so arranged as to discharge every quarter of an inch that falls, when the pencil again starts at zero.

Suggestions as to the probable Causes of the Aërial Currents of the Temperate Zones. By Mr. Birt.

Mr. H. W. Dove has lately proposed, Phil. Mag. Sept. 1837, a Theory to account for the variations in the direction of the winds, on the principle that the earth's rotatory motion produces a change in the direction of a stream of air passing over any given place in the temperate zones, occasioning a northerly current to become easterly, and a southerly one westerly.

The author presented a diagram of the directions of aërial currents observed, and offered suggestions as to the probable causes of the variations in these directions. The general tendency of the wind being understood to vary in the order of S.E., S., W., N., N.E. during the direct periods, and N.E., N., W., S., S.E., during the retrograde, the author proposes the following explanation.

The heated air from the intertropical regions flows over towards the poles, giving rise to currents in every possible direction on either side of the torrid zone, and as the sun is vertical to a spot which traverses a parallel of the torrid zone during twenty-fours, it is evident that the currents thus generated are extremely numerous, and situated in every possible direction with respect to any given place within the temperate zones, London for example; this will be readily apparent upon inspecting a terrestrial globe, when it will be seen that the spaces some of these currents have to traverse previous to their arriving at London are of much greater extent than others, and they will consequently arrive at the place of observation much later. Now supposing these currents

to be formed about the 30th parallel of north latitude for the northern temperate zone, those which originate between two hours east and two hours west longitude as the sun traverses this portion of the torrid zone, and are directed towards England, will reach London between the S.E. and S.W. points, the S.E. and S. currents arriving first; these will be succeeded by the S.W., and as the sun passes on in his progress the currents arrive at London with a more westerly direction, and those originating between four and five hours west, which are nearly S.W. at the 30th parallel, become W. at London. In this manner the currents vary, following the course of the sun, until he arrives at the 10th meridian west of Greenwich; the current produced here reaches London as a N.W. wind, while that moving towards the north in longitude 180° arrives at London as a N. wind. As the currents produced at places situated more and more westerly of 180° arrive, they acquire a more easterly character, until the sun reaches between five and four hours east, when the direction of the wind becomes east, the N.E. originating at ten hours east, as the N.W. originated at ten hours west; the wind then progresses to S.E., and the same order recommences.

The above account of the formation of currents on the equatorial boundaries of the temperate zones the author supposes will sufficiently explain the progression of the wind round the compass in a direct order; and in consequence of the large space which the currents (that are formed near the opposite meridian) have to traverse, compared with that which the southern currents pass over, the greater prevalence of S.W. winds is readily accounted for. England, however, from its position in the north temperate zone, is subjected to the influence of those currents that proceed from the pole towards the equator to supply the place of the air which ascends by the heating power of the sun; these currents arrive at London from all points between W. and E. towards N. in the order W., N., E. and may concur in their arrival with the N.W.,N. and N.E. equatorial currents, or the S.E., S., and S.W., producing a diversity of phænomena according as they are situated W. or E. of them. If for instance a N.W. polar current arrives with a N. equatorial, the resultant wind is N.N.W.; and if the equatorials have steadily proceeded from S.E. to N., in consequence of the position of the two kinds of currents, a regression will take place, which will be greater the further the winds are from each other: this state of things will considerably influence the remaining winds which, combined with the meeting of differently posited equatorial currents, may induce a permanent regression of a greater or less magnitude, and which gives place to a direct order, upon the polar currents preceding the equatorial in their arrival. These views, the author conceives, will sufficiently explain the variations exhibited in his diagram, which suggests the idea, that the revolutions of the equatorial and polar currents are extremely regular, and that the antecedence and consequence of the polar relative to the equatorial currents are subject to laws capable of being ascertained by careful observation. During the first half of the period tabulated, there were two alternations of the equatorial and polar, and during the latter half the same alternations occurred in a reverse order.

On the higher Temperature which prevails in the Slate than in the Granite of Cornwall. By W. J. Henwood, *F.G.S., Member of the Geological Society of France, H.M. Assay-Master of Tin in the Duchy of Cornwall.*

It is not very easy to devise an unexceptionable mode of ascertaining the temperature natural to any given spot under-ground.

In the experiments (about the earliest) of Trebra*, and in the later and most valuable ones of Cordier, the thermometer was inserted in a hole in the rock; to which it may be objected, that if it be exposed to the action of a stream of water, it will indicate the temperature of the liquid; and if but a little ooze out of the rock, its evaporation will reduce the heat; whilst at all times the influence of the air with which the gallery (level) is filled will affect it to some depth, and this is sometimes perfectly still, and at other times in rapid motion, often coming from parts of the mine where workmen are numerous, and frequently from the surface, depending on the direction of the wind, which very often in its changes reverses the direction of the subterranean currents.

The same reasons have long induced observers to abandon the temperatures of air and of stagnant pools of water in mines.

Streams of water issuing from the unbroken rock are less liable to be affected by several of these influences, as they are not likely to be much disturbed by the few last beds of rock through which they percolate; but whether they indicate the temperature of the level where they appear, or of some higher or lower spot, is not so readily ascertained, and can after all be but suspected from their coincidence with the prevailing tenor of other observations. This last is, however, Mr. Henwood thinks, less objectionable than the other modes, and is that which he has himself pursued in the observations, of which an abstract is annexed.

SLATE.				GRANITE.			
Depth (fathoms.)	Average Depth (fms.)	Number of Observations.	Temperatures.	Depth (fathoms.)	Average Depth (fms.)	Number of Observations.	Temperatures.
Surface to 50	35	21	57°	Surface to 50	31	7	51°·6
50 „ 100	73	19	61°·3	50 „ 100	79	17	55°·8
100 „ 150	127	29	68°	100 „ 150	133	12	65°·5
150 „ 200	170	21	78°	150 „ 200			
200 and beyond	221	5	85°·6	200 and beyond	237	3	81°·3

* *Annales des Mines*, i. 377, for the year 1817.

Thus the Slate at all depths appears to be about 3°·9 warmer than the Granite at the same level.

The progressive increase of temperature in descending is on a mean of

95	Observations in the	*Slate*	1° for	6·5 fathoms
39	„ „	Granite	1° „	6·9 „

Statement of the Proceedings of the Meteorological Committee, consisting of Prof. FORBES, Mr. W. S. HARRIS, Prof. POWELL, Lieut.-Col. SYKES, *and* Prof. PHILLIPS, *during the past year.*

Prof. Phillips then presented a statement of the Proceedings of the Meteorological Committee during the past year. The objects proposed by the Association in the appointment of the Committee were two-fold: first, the institution of uniform experiments, for the acquisition of accurate data concerning the distribution of temperature, from the surface of the earth downward to the greatest depths attainable by human enterprise; secondly, the establishment of well-arranged observations on the varying phænomena of the atmosphere, which can be elucidated by combined exertions on one plan, and for the same object. The Committee had thought it best to employ the sum placed at their disposal on one of these objects only, so as to effect with regard to it a real advance, reserving to themselves the hope that, by a further grant, they might be enabled effectually to turn their attention to the second branch of investigation—viz. atmospheric phænomena. One hundred pounds had been granted, and seventy-two thermometers, and proper tables for being filled up, had been distributed by the Committee.

Confining himself to the principal points disclosed by the results yet received from the several observers, it appeared that the general truth of the regular augmentation of temperature in proceeding downwards from the surface of the earth, was confirmed; but that, in addition, the different distribution of water, the nature of the rocks, and other causes, produced local discordances. The last of these causes appeared to the Committee of such importance, not only for the explanation of these differences, but for purposes of general reasoning in physics, that Professor Forbes was requested to institute a complete series of continuous experiments, which he had devised, similar in general principle, and at corresponding depths below the surface of the ground, to those established by M. Quetelet, at Brussels, so as to determine *the rate* of communication of heat, *in one uniform mass*, from the surface downwards to the depth of 26 feet; and further, to ascertain the *differences of this rate in materials of different kinds*, by a triplicate course of observations in trap-rock, sandstone, and a uniform mass of sand.

The observations established by Professor Forbes have been regularly registered at the Botanic Garden, in Cragleith Quarry, and on the Calton Hill, from February to September 1837, and the register was laid before the meeting. Particular precautions were taken not only

to provide for the safety of the instruments, but also to allow of the application of a correction for any variation which they may undergo. Moreover, the method of experimenting on local temperature, proposed by M. Peltier, by using a thermo-multiplier, was applied by Mr. Forbes, and as far as a few observations could be relied on, the agreement of the two methods was remarkable; but it was not thought proper to state the results of the experiments till they could be supported by one or more complete circles of observations.

On a Method of constructing Magnets. By JAMES CUNNINGHAM.

Having turned his attention to the construction of powerful magnets for electro-magnetic machines, the author tried steel of various qualities, but without satisfactory results. He finally tried cast iron, run into moulds of the required horse-shoe form, and found these highly carbonaceous masses remarkably retentive of magnetic power.

On the possibility of effecting Telegraphic, or Signal Communications during Foggy Weather, and by Night in all Seasons. By Colonel C. GOLD.

On an Instrument for Measuring the Electricity of the Atmosphere. By Lieutenant MORRISON, R.N.

CHEMISTRY.

On the Products of the Decomposition of Uric Acid. By PROFESSOR LIEBIG.

"The important part which uric acid performs in the animal economy has for a long time attracted the attention of the most distinguished physicians and chemists. Uric acid forms in one class of animals the whole of the excrement, and in another class it is its principal constituent, and it is accompanied by urea, a never-failing constituent of the human urine. Its extraordinary production in that morbid state of the body, which we call a predisposition of gout, is well known to give origin to one of the most painful diseases to which mankind is liable. It may be affirmed, with the utmost certainty, that urea and uric acids are products of the organization. We cannot discover their existence in any part of our food, nor do they constitute a part of any organ, as fibrin does of the blood, but they are chemical combinations

of a peculiar nature, on which account they come more within the range of chemical investigation than any other bodies of animal origin. Prout's masterly analysis has long since removed every doubt respecting the composition of urea, and the extraordinary, and, to some extent inexplicable, production of this substance without the assistance of the vital functions, for which we are indebted to Wöhler, must be considered one of the discoveries with which a new era in science has commenced. Wöhler observed, that when cyanic acid is made to combine with ammonia, the product is urea; and he and I have, in a set of experiments which we made together, proved that these two bodies, when first combined, form cyanate of ammonia, a salt analogous to every other ammonia-salt; that is to say, the base can be replaced by other bases, and the acid by other acids; but that a few minutes after the combination has taken place, all these properties disappear. We can no longer detect either ammonia or cyanic acid; a new substance has been formed, entirely different from every other chemical compound. To follow out the characters of urea would here be quite out of place; it was however necessary to allude to it from its intimate relation to uric acid.

"The elementary composition of uric acid has also been established beyond a doubt. We are certain that it may be expressed by the formula $C_{10} N_4 H_4 O_6$. We know, also, that this acid combines with the different bases, and forms salts. Inorganic chemistry is satisfied with the determination of these properties; but it must be evident that the formula can give us no idea of the manner in which the elements are united together to form the substance. If we admit the principle that no ternary or quaternary compound can be formed except by the union of a binary compound with an element, or of two binary compounds with one another, it is clear that any further investigation of uric acid must be carried on with the intention of discovering the compound elements into which it may be resolved.

"This investigation, which promised to yield the most important results both for medicine and chemistry, Professor Wöhler and I determined to undertake together. In medicine, it was evident that we might have some new method of destroying calculi in the human bladder without the application of external force. In chemistry, the most interesting discoveries were also to be expected, as we had not the slightest doubt that urea, xanthic acid, cystic oxide, oxalic acid (which last substance is well known to constitute frequently an ingredient in urinary calculi), that all these bodies are produced by the decomposition of one single substance, and that substance uric acid.

"Our analytical investigations of these various bodies have not yet made sufficient progress to enable me to communicate them here. My intention at present is, to point out the plan which we followed in our attempts to decompose uric acid into its proximate elements, and the singular results which we obtained. But, before proceeding to do so, I wish to notice a very remarkable compound, which will, I think, serve greatly to illustrate the subject we are at present occupied with.

"Winkler found that when the distilled water of bitter almonds was mixed with muriatic acid, a new acid was obtained. The distilled water of bitter almonds, in a pure state, contains nothing but prussic acid and oil of bitter almonds (hydret of Benzoyl). When treated with muriatic acid, we obtain sal ammoniac and the new acid, and nothing else. It is evident from this, and the conclusion is corroborated by the ultimate analysis of the new acid, that the hydrocyanic acid of the liquid is decomposed by the action of the muriatic acid into ammonia and formic acid, that the ammonia combines with the muriatic acid, and that the formic acid, in the nascent state, unites with the oil of bitter almonds to form a compound acid in which the power of saturation of the formic acid is not changed. This acid performs in every respect the part of a simple acid; and its existence has rendered probable the supposition, that the same views respecting other acids are not without foundation. Another interesting fact respecting this acid is that when heated with hyperoxides it is decomposed in a particular manner, only one of its proximate constituents being oxidized, while the other suffers no change. The products obtained are carbonic acid and oil of bitter almonds.

"Now, I think it must be evident to every one that uric acid must possess a composition similar to that of the acid just mentioned, and therefore that its oxidation in the same manner would in all probability lead to interesting results. We obtained, in fact, results which corresponded to our expectations. Uric acid may be considered as a compound of urea with a peculiar acid; that is, we may view it as analogous to nitrate of urea. This acid contains the radical of oxalic acid combined with cyanogen. I have attempted to show, in some former researches, that carbonic oxide, and not carbon, constitutes the radical of carbonic acid and of oxalic acid, and that phosgene gas might be considered as containing the same radical in combination with chlorine. If we indicate carbonic oxide by R, these compounds will be as follows:

1. Phosgene gas $R+Cl$. 2. Carbonic acid $R+O$. 3. Oxalic Acid $2R+O$.

"Now the acid which combines with urea to form uric acid may be expressed by the formula $R+Cy$. Viewed in this manner, the composition of uric acid will be $4(R+Cy)+Ur$.

"Uric acid, when heated with brown hyperoxide of lead, was decomposed into three different products, oxalic acid, urea, and a peculiar substance which we may view as a compound of cyanogen and water, and which is identical with a body long known, called allantoic acid, from having been first found in the allantoic fluid, but which it would be better to call allantoin, as it is capable of acting equally as an acid and a base.

"One atom of uric acid decomposed by the action of two atoms of hyperoxide of lead, is converted (supposing 3 atoms of water to be present,) into 2 atoms oxalate of lead, 1 atom of allantoin, and 1 atom of urea.

1 atom Uric Acid + 2 atoms Hyperoxide of Lead,
$(C_{10}\,N_4\,H_4\,O_6)+Pb_2\,O_4$,
gives
(R_4+O_2) Oxalic Acid + 2 PbO Oxalate of Lead two atoms,
$(4\,Cy+3\,Aq)$ Allantoin,
1 atom Urea.

"Allantoin is the second body belonging to the animal organization which we can form artificially in the laboratory. This substance can also be directly produced by the decomposition of cyanogen and water. It yields, when decomposed by other bodies, all the products which, from its formula, might be expected. Thus, with alkalis it yields oxalic acid and ammonia; with strong sulphuric acid, carbonic acid, and carbonic oxide.

"There are many bodies similar to urea and allantoin, all of which will probably, at a future period, be produced by artificial means; but in order to arrive at this, the final object of investigation in organic chemistry, a great deal of labour, and that labour of a combined nature, will be required. I am certain that this object will be obtained. Organic chemistry has made its first step, and already its field has been extended to a very surprising degree. We meet every day with new and unexpected discoveries. It is, however, remarkable, that in the country in which I now am, whose hospitality I shall never cease to remember, organic chemistry is only commencing to take root. We live in a time when the slightest exertion leads to valuable results, and, if we consider the immense influence which organic chemistry exercises over medicine, manufactures, and over common life, we must be sensible that there is at present no problem more important to mankind than the prosecution of the objects which organic chemistry contemplates. I trust that English men of science will participate in the general movement, and unite their efforts to those of the chemists of the Continent, to further the advance of a science which, when taken in connection with the researches in physiology, both animal and vegetable, which have been so successfully prosecuted in this country, may be expected to afford us the most important and novel conclusions respecting the functions of organization."

Extracts from a Letter received by Dr. DALTON *from* PROFESSOR HARE.

Philadelphia, August 14th, 1837.

Dear Sir,—I beg leave through you to communicate to the British Association for the Advancement of Science the fact that, by an improvement in the method of constructing and supplying the hydro-oxygen blowpipe, originally contrived by me in the year 1801, I have succeeded in fusing into a malleable mass, more than three-fourths of a pound of platina. In all I fused more than two pounds fourteen ounces into four masses, averaging, of course, nearly the weight above mentioned. I see no difficulty in succeeding with much larger weights.

The benefit resulting from this process, is in the facility which it affords of fusing scraps, or old platina wire into lumps, from which it may be remodelled for new apparatus.

The largest masses were fused agreeably to my original plan of keeping the gases in different receptacles, and allowing them to meet during efflux.

I have, however, operated in the large way upon the plan contrived and employed by Newman, Brooke, Clarke, and others, having employed as much as thirty gallons in one operation of the mixture of the gaseous elements of water. This I was enabled to do with safety, by an improvement in Hemming's safety tube. In this improved form I have allowed the gas to explode as far into the tubes of efflux as the point where the contrivance in question was interposed, at least a hundred times, without its extending beyond it.

Still, however, the other mode in which the gases are kept separate, until they meet in passing out of their respective receptacles, is less pregnant with anxiety, if not with risk. As these elements are known to explode by the presence of several metals, other mysterious modes may be discovered.

Having made a self-regulating reservoir of chlorine, by suspending lump peroxide of manganese in concentrated chlorohydric acid, I was surprised by a violent explosion on presenting leaf metal to the jet tube. I had made similar apparatus before and have repeated the process with the same materials since, without a repetition of the explosive reaction. It might be inferred, that the protoxide of chlorine was generated, but the colour of the gas was so inferior in intensity to that of chlorine, as to lead me to suppose that there was some irregularity, before testing it with Dutch gold leaf. It has occurred to me that there may be a dichloride of hydrogen, which may explode with chlorine, and that of these the mixture consisted which produced the phenomenon in question.

In freezing water, by the vaporization of ether, the labour of pumping is lessened, and the pump protected from a disadvantageous introduction of the vapour, by interposing sulphuric acid. If the stem of a funnel, with a cock, be luted into the tubulure of a retort, and the beak of the latter into the neck of a receiver, of which the tubulure communicates with an air-pump,—on placing water in the funnel, ether in the retort, and sulphuric acid in the receiver, and exhausting, then allowing the water to descend into the ether, the congelation of the water is rapidly effected. Of course the acid absorbs the etherial vapour with great force, and the resulting mixture or rather combination requires a temperature of at least 280° for its ebullition. This is less consistent with the doctrine of Mitscherlich than that of Hennell.

On the Specific Heats of Nitric Acid and Alcohol. By T. Thomson, *M.D.*

NITRIC ACID.

Composition.		Sp. Gravity.	Sp. Heats.
Atoms acid.	Water.		
1	+ 1·37	1·5040	0·4645
1	+ 2	1·4862	0·5138
1	+ 3	1·4477	0·5553
1	+ 4	1·4177	0·5834
1	+ 5	1·4005	0·6021
1	+ 6	1·3724	0·6415
1	+ 7	1·3598	0·6495
1	+ 8	1·3235	0·6832
1	+ 9	1·3007	0·6941
1	+10	1·2815	0·7239

ALCOHOL.

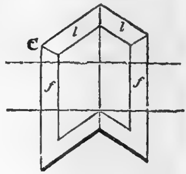
Composition.		Sp. Gravity.	Sp. Heats.
Absolute........		0·7950	0·6600
Atoms. Alcohol.	Atoms. Water.		
4	+ 1	0·8179	0·6775
3	+ 1	0·8259	0·7576
2	+ 1	0·8384	0·8034
1	+ 1	0·8672	0·8466
1	+ 2	0·9042	0·9210
1	+ 3	0·9266	0·9915
1	+ 4	0·9412	0·9962

On the unequal expansion of Minerals in different directions by Heat. By Professor Miller, *F.R.S.*

The slice of gypsum, he observed, which had been sent him by Prof. Mitscherlich, was a portion of a twin crystal, bounded by two parallel polished surfaces, cut perpendicularly to the faces *f* and to the direction of cleavage, which passes uninterruptedly through both individuals. In consequence of the unequal expansion, in different directions, of gypsum when heated—a fact first discovered by Mitscherlich—the portions of the two individuals of the twin crystal, when heated, alter their form; and the artificial section of the two crystals, which,

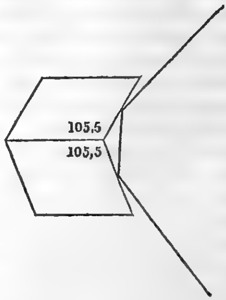
at the ordinary temperature of the air forms one continuous plane, becomes distinctly two planes, making a very obtuse angle with each other, and meeting in the line of junction of the two crystals.

Artif. Sec.



The alteration of the angle between the two edges that meet at C, amounts to 7′ 26″ for a change of temperature of 100° centigrade, the angle being more obtuse when the crystal is hot than when it is cold.

The fact of the unequal expansion of crystallized bodies in different directions, was first established by Mitscherlich, in the case of calcareous spar, by actually measuring the angle between the planes at low temperature, and when the crystal was heated. The change due to 100° centigrade was 8′ 34″, the angle between the cleavage planes, which at ordinary temperatures is 105°, 5′, becoming smaller when the crystal is heated. Prof. Miller's way of showing it is as follows:—Two rhombohedrons are clamped together, with their obtuse edges in contact—the two crystals are then held so that the flame of a candle may be seen, after two reflexions, one at each of the two surfaces of the crystals, which form a re-entering angle. By a well-known optical property, the angle between the candle and its reflected image, as seen by an eye close to the crystal, will be twice the angle between normals to the reflecting planes. Hence, if, when heated, the angle of each crystal undergoes a change ε, the angle between the normal salters b2 ε, and the angle between the candle and its image, as seen from the crystals, by 4 ε.



In his observations, the image of the candle is viewed through the telescope of a theodolite. The angle through which the telescope revolves, in order to keep the image of the candle always bisected by the cross wires, of course measures 4 ε. A good method of heating the crystals is by a small crucible, quite full of mercury, heated by a lamp, into which the lower part of the crystals is immersed, as also the bulb of a thermometer. The clamp must not be strong, but a kind of weak spring, in order that the crystals may experience no mechanical obstruction to their change of form.

Observations on the Crystallization of Metals by voltaic action, independent of the proximity of metallic electrodes. By GOLDING BIRD, *M.D., F.L.S., F.G.S., Lecturer on Experimental Philosophy at Guy's Hospital, &c.*

It is well known that one of the latest discoveries on the conditions of electrolytic action has been to observe, that the presence of metallic or solid electrodes was not necessary to the production and perfection of true polar decomposition; this fact among a host of others with which that philosopher has enriched science, was announced by our illustrious countryman Dr. Faraday.

Results depending on the same principle occurred to the author whilst engaged in a series of experiments on the electrolytic energy of electric currents of feeble tension, some of which have been described in a paper read before the Royal Society of London, in February 1837, and since inserted in the "Philosophical Transactions," and appeared to partake of perhaps more than ordinary interest, from the very feeble intensity of the voltaic current required for their success, as well as from their analogy to what, perhaps, is going on in the great laboratory of nature, in effecting the reduction and crystallization of metals. The voltaic apparatus used consists of an exceedingly simple arrangement:—a cylinder of glass, about 8 inches in height and two inches in diameter, forms the exterior vessel or cell of the battery; immersed in this, is a second cylinder, 4 inches in height, and about 1·5 inch in diameter, open at both ends; a plug of plaster of Paris, about 2 inches thick, is made to fit its lower half accurately, by being poured in whilst as thin as cream, forming, on its becoming solid, a firm but porous base to the cylinder. The external cylinder is then filled with a weak solution of common salt (chloride of sodium), whilst the internal cylinder is filled with a solution of a metallic salt, (as sulphate of copper,) which becoming rapidly imbibed by the porous plug of plaster of Paris, comes in contact with the brine in the exterior vessel, without, however, causing their intermingling rapidly. A plate of polished copper soldered to a thick wire or ribbon of the same metal is then plunged into the solution of the sulphate of copper, whilst a plate of zinc connected to the other end of the copper wire is immersed in the solution of common salt. Under these circumstances it is obvious that an electric current becomes developed, the positive fluid escaping from the copper to the zinc along the connecting wire, back through some inches of brine to the plaster of Paris plug, thence to the copper solution, which it has to penetrate before it can gain the copper plate which serves for the negative electrode. The zinc plate becoming electro-positive determines the decomposition of the water, uniting with its oxygen to form oxide of zinc, which uniting with the hydrochloric acid of the common salt sets the positive elements, hydrogen and soda, at liberty, determining their evolution at the negative electrode; they, however, in their passage effect the decomposition of the sulphate of copper and cause the precipitation of metallic crystals on the copper plate; or we may suppose that in the first instance the zinc plate effects the decomposition of the

common salt, as *chloride* of *sodium*, chloride of zinc being formed, and sodium evolved, which, in its passage through the copper solution, effects its decomposition and reduction on the surface of the negative electrode. On either hypothesis the ultimate electrolytic action produced must be regarded as the secondary, and not as the primary and immediate effect of the voltaic current. The copper reduced on the surface of the negative electrode, is (as is well known) not brown and spongy, as when more intense currents are employed, but hard and crystalline as in native specimens, the crystals being frequently intermingled with those of the ruby-coloured protoxide, in which case their resemblance to the native mineral is most remarkable.

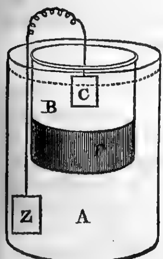
After leaving an apparatus of this kind just described to itself *for some months*, the fluid in the interior cylinder had lost nearly all its blue colour, scarcely a trace of copper being present, it having become a tolerably pure solution of sulphate of soda; but on examining the surface of the copper-plate immersed in it, the quantity of reduced copper was found considerably less than one quarter of the quantity previously present in the sulphate. Dr. Bird, being unable satisfactorily to account for this loss, was led to examine the contents of the cylinders with the greatest care; and on removing the plaster of Paris plug, which had now become quite soft, and lixiviating it with water, he had the pleasure of meeting with numerous, very hard, and beautifully defined crystals of metallic copper, imbedded in the thickness of the mass of sulphate of lime, not merely in scattered and isolated crystals, but in distinct and continuous veins. Some of these veins were distinctly visible without breaking up the mass of plaster, being spread in a curiously ramified manner, like the branches of a tree, on that part of the plaster in contact with the glass. These metallic crystals must have been reduced from that portion of the copper solution absorbed by the plug of sulphate of lime, simply by the passage of the current of electricity from one electrode to the other, notwithstanding no metallic, or even solid connection of any kind existed between the reduced crystals of copper and the negative electrode. The result of this experiment is therefore interesting, if it only serves to confirm the observation of Dr. Faraday, that the presence of a solid electrode is by no means necessary for the perfection of electrolytic action, for we here see crystals of metallic copper produced at a distance midway between the electrodes of metal, and at some inches from either. But this experiment is interesting in another and perhaps more important point of view, as it tends to throw some light on the mysterious and interesting process of the reduction of metals, and formation of metallic veins in the bowels of our earth.

The author then showed the bearing of these results on the question of the influence of electrical currents in arranging the materials of mineral veins.

If, in the apparatus above-described, a plate of clear lead is substituted for one of copper, for the negative electrode, and a solution of acetate or nitrate of lead, for sulphate of copper, an electric current will of course be set in motion, and spangles of reduced lead will

appear upon the negative plate; and, after some weeks of continued action, small veins of crystalline lead will be found permeating the mass of plaster of Paris in an exceedingly elegant and arborescent form. Similar results are obtained when plates and solutions of zinc, tin, antimony, silver, and many other metals, are substituted for those of copper and lead. These experiments, moreover, are by no means liable to failure from slight causes, the results being always constant.

Having thus proved that well-defined crystals of metals are obtained, if sufficient time is allowed, by allowing a current of the feeblest intensity to permeate a porous substance, imbued in a metallic solution, without the presence of poles or supposed attracting points, Dr. Bird was anxious to ascertain how far this process might be applied to the artificial fossilization of wood, by injecting (as it were) by voltaic action, every part of its permeable tissue with crystalline metals. Some few experiments on this head, which he has performed, seem to promise the most perfect success; and the author hopes to present an account of the results to the next meeting of the Association.



A. The exterior cylinder containing brine.
B. The inner cylinder containing the metallic solution.
C. The copper electrode on which metallic crystals are formed.
Z. Zinc or positive electrode.
P. The thick plaster plug, (closing the cylinder B,) in which veins of the crystalline metals become formed by the passage of the current from Z. to C.

On the formation of Crystallized Metallic Copper in the shafts of the Cronebane Copper Mine, County Wicklow, Ireland, and of native Sulphate of Iron and Copper on the same locality. By R. Mallet, *M.R.I.A.*

Metallic copper has been frequently obtained, as is well known, by various methods in the laboratory, and in large masses in Daniell's Constant Batteries; but the present is the first occasion on which native copper has been found, actually detected, as it were, in the very act of formation in the mine shaft.

The Cronebane mine has been wrought for a very lengthened period, and has an additional interest as connected with the present subject, from the electro-magnetic condition of the next mine to it, the Connoree, which is part of the same vein, having been determined by Mr. Petherick. (*Philosoph. Mag. 3rd Series*, vol. iii.) He found it deflected the galvanometer needle 18°—that the ore was negative, and the ground positive. The lode is situated in clay slate, dipping to the

S.W. The mine water is strongly cupreous, and deposits a slimy sediment of iron, and organic matter, probably "Glairine." In this slime, and adherent to the timbering of the mine, the crystals of pure malleable copper were found in considerable quantity. The mine water from whence these masses were formed, has a specific gravity of 1·032, at 58° Fahr. When evaporated to dryness, it leaves a horny residue, smelling of animal matter. It contains the mixed sulphates of copper and iron.

Amongst the many forces in operation to produce this metallic aggregation, the author suggests the possibility of galvanic action, between the lode and the timbering of the mine; having found the galvanometer much affected by a small series of plates of grey copper ore, and of fir timber, saturated with solution of sulphate of copper under the air pump—the exciting fluid being the water of this mine. The slime appears to act the part of Becquerel's clay plugs, or Wach's diaphragms.

The author also presented a specimen of native sulphate of copper and iron, from the same mine; from the ochrey slime at the bottom of a shaft of fifty fathoms deep, which had been full of water for above a century. It is found in small, brilliant, blueish green, rhomboidal crystals, and consists, according to the author's analysis, of—

Sulphate of Iron	34·2
Sulphate of Copper	65·7
	99·9

This analysis does not present any exact atomic proportion between the two salts, taking the atom of sulphate of copper to weigh 15·62 as determined by Dr. Thompson, and containing five atoms of water; but it is remarkable, that if the sulphate of copper be supposed to be the green sulphate, which contains but one atom, and has an atomic weight of 11·12, the above analysis will correspond to three atoms of green sulphate of copper, and one atom of sulphate of iron. In favour of this view is the circumstance, that these crystals were formed at a considerable depth, and consequent high temperature; and that it is by similar means that the green sulphate of copper is artificially formed. On the other hand, while the common sulphate of copper is isomorphous with the sulphate of iron, that which has but one atom of water is not so; it crystallizes in right prisms, while the common sulphate of copper assumes the form of the double oblique prism. It is possible, however, that the crystalline form of the green sulphate may be modified by the presence of the sulphate of iron.

On a new Chemical Compound. By Dr. APJOHN.

This new and very complicated compound, including iodide of potassium, iodine, and what Dr. Apjohn denominated Cinnamile, from its analogy to benzoyle, the hypothetic base of the essential oil of almonds, was exhibited to the Section. The compound was formed

accidentally during the prevalence of cold weather, in a mixture prescribed by a physician, and which contained iodide of potassium, and iodine dissolved in cinnamon water, prepared by the ordinary pharmaceutical process. It was first particularly noticed by Mr. Moore, of Anne Street, Dublin, in whose establishment the prescription was made up. He made several experiments upon it; and, having furnished Dr. Apjohn with a specimen of it, they undertook conjointly the further determination of its properties, and the investigation of its composition. It occurs in long capillary four-sided prisms, of a beautiful bronze aspect, melts at about 82°, dissolves in alcohol and ether, but is decomposed by water. This latter menstruum, however, has no action upon it when it holds iodide of potassium dissolved, or probably other kinds of saline matter. Mercury effects its decomposition, an iodide of mercury being formed, and iodide of potassium, with (probably) cinnamile, being liberated. By an elevated heat it is decomposed, iodide of potassium being left, with a considerable quantity of charcoal, while iodine, and an organic vapour smelling of the oil of cinnamon, pass off. Dr. Apjohn stated, that according to his experiments, which however were not completed, it would appear to be composed of one atom of iodide of potassium, associated with two of the subsesqui-iodide of cinnamile, as represented by the following formula:

$$\mathrm{I\,K} + 2\,(\mathrm{I}_2\,\mathrm{Cin.}_3)$$

This he stated to be the formula which most nearly expresses his analytic results: but he added, that he did not place much confidence in them; and that, not having as yet been able to effect the combustion of the compound with oxide of copper, he should not be surprised at finding this formula materially corrected by the results of the further researches with which he stated himself and Mr. Moore to be at present occupied*.

On a new Variety of Alum. By DR. APJOHN.

The mineral in question was received from Mr. Atherton, an African gentleman, and was found on the eastern coast of the African continent, about midway between Graham's Town and Algoa Bay. It occurs in fibrous masses, very similar to asbestos, having a beautiful satiny lustre, and splitting into threads which would appear to be quadrilateral prisms. In taste, solubility in water, and relation to several reagents, it closely resembles ordinary alum, but is distinguished from it by containing protoxide of manganese, instead of an alkali, and by not assuming the octahedral form. In symbols it is represented by

$$(3\,\mathrm{S\,O}_3 + \mathrm{Al}_2\,\mathrm{O}_3) + (\mathrm{S\,O}_3 + \mathrm{Mn\,O}) + 25\,\mathrm{H\,O},$$

* Dr. Apjohn has since found that this compound includes not Cinnamile but the oil of Cinnamon itself, and that its true formula is $(\mathrm{IK} + 3\,(\mathrm{I} + \mathrm{Cin}_2)$. (See Proceedings of the Royal Irish Academy for 1838, page 162.)

a formula identical with that which belongs to the entire genus of alum salts. Dr. Apjohn briefly alluded to the other varieties of alum, both those in which the alkalies replace each other, and those in which the alumina is replaced by the deutoxide of iron, chrome, or manganese; and pointed out the theoretical possibility of an alum containing no metal but manganese.

On a new Gaseous Compound of Carbon and Hydrogen. By E. DAVY, *Professor of Chemistry, Dublin.*

The gas (a new bicarburet of hydrogen), which was described by Professor Davy at the last meeting of the Association in Bristol, having been inclosed in a tube furnished with platinum wires, and subjected to a series of electric sparks, carbon was deposited, but there was no alteration of volume. This residual gas the author conceives to be new. It is insoluble in water; not ignited by chlorine; exploded with one and a half volume of oxygen, it gives one volume of carbonic acid and some water. This gas would therefore appear to be a binary compound, and to be represented by the formula $C+H$. Professor Davy stated, that his investigations were not concluded, but that he hoped to be able to give a fuller paper on the subject at the next meeting of the Association.

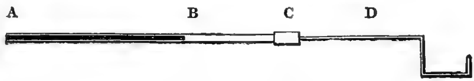
Outline of an experimental Inquiry into a peculiar Property of the Earth; the chemical Changes which occur during the germination of Seeds; the vegetation of Plants; the formation of vegetable Products; and the renovation of the Atmosphere; with some Observations on the ultimate analysis of Organic Compounds; the whole being in connexion with a series of investigations into the decomposition of Vegetable Matter. By ROBERT RIGG.

The extensive class of subjects included in the title of Mr. Rigg's communication had been investigated by the author through the medium of many thousand experiments, the results of which appeared to him to establish an harmonious connection between them all, of which the following is an abbreviated sketch. *The earth* retaining water, and combining with carbonic acid gas the food of plants; the *seeds*, decomposing the water, forming carbonic acid gas, and a compound of carbon, hydrogen, nitrogen, and earthy matter; the *germ* which favoured this peculiar decomposition, uniting the latter compound with the oxygen of the atmosphere; the *roots*, promoting the further decomposition of the water, forming carbonic acid gas, and the other compound, (the earth taking up the former if it be not immediately wanted, the latter entering into the plant as sap); the *leaves*, serving the office of reservoirs for atmospheric air and moisture, and for performing certain offices respecting the changes effected upon carbonic acid gas; the *whole plant*, combining the different elements, so as to form the oils, resins, gums, &c. to an unlimited extent.

Again, we have the *whole plant* renovating the atmosphere, both as regards oxygen and nitrogen, and preserving an equilibrium throughout the different seasons; *each plant* decomposing water, and assimilating other portions of it, by methods peculiar to itself; in the *vinous fermentation*, the carbon (of sugar for instance), when nitrogen and earthy matter are present, decomposing water, forming carbonic acid gas, olefiant gas, and a minute quantity of azotic gas; in the *acetous fermentation*, the oxygen of the atmosphere, uniting with this olefiant gas, forms acetic acid and water, a portion of vegetable and earthy matter being necessary; and, in the *decomposition of vinous fluids*, the oxygen of the atmosphere combines with the carbon of the olefiant gas, to form carbonic acid, and with the hydrogen to form water, vegetable and earthy matter being essential.

The author, referring to the difficulties which, in his opinion, particularly embarrass experiments on the mixed results of fermentation, gives a brief notice of his mode of analysis in these cases.

The apparatus which he employs in ultimate analysis is included in two glass tubes, connected by caoutchouc, as under:



A. The part containing the mixture of black oxide of copper and the compound under analysis.

B. Amianthus in the same tube, which condenses the steam, and dries the gases. It is kept cool by moistening blotting paper with spirit.

C. Caoutchouc connecter, about an inch in length.

D. Bent thermometer tube, for conveying the gaseous products to the receivers standing over mercury.

The analysing tube A B rests upon a frame, made of two pieces of strong wire, bent at each end at right angles, and kept together by smaller wires. These, together with tubes, for detecting minute quantities of nitrogen, and lamps, which will give off flames from one to six inches in length, constitute the whole apparatus.

On a Variety of Ozocerite. By PROFESSOR JOHNSTON.

This substance was found in a coal-mine near Newcastle. It consists of three distinct principles; the one being soluble in cold, the other soluble in hot ether, and the other nearly insoluble in both. The first is the most abundant of the three, and upon analysis is found to be a binary compound of carbon and hydrogen, and therefore to be an addition to the already extended list of isomeric combinations of these elements. The whole mass submitted to ultimate analysis gave exactly the same result.

New Compound of Nitrate with Oxalate of Lead.

Mr. Johnson also exhibited a new compound of nitrate with oxalate of lead in beautiful pearly scales and flat six-sided plates longitudinally striated. It is formed when a solution of subacetate of lead is poured into one of oxalic acid in which much nitric acid is present. It contains two atoms of water, and its formula is $\dot{Pb}\,\overset{\cdot\cdot\cdot\cdot\cdot}{N}+\dot{Pb}\,\dddot{C}+2\dot{H}$.

On a Series of Compounds obtained from Pyroacetic Spirit. By Dr. Kane.

(See on this subject Dr. Kane's paper, printed in Lond. and Edinb. Philosophical Magazine, vol. xii. p. 100.)

On the Smelting of Iron with Anthracite Coal. By G. Crane.

The great extent of the deposit of anthracite (or stone coal) in the mineral basin of South Wales, accompanied as it is with iron mine in great abundance, and of good quality, has long made it an object of great interest to parties connected with that district to discover some method of applying that description of coal to smelting purposes.

One of the earliest patents enrolled in this country for this object was that of Mr. Martin, in 1804. From the mode detailed in his specification, there does not appear to have been any peculiarity in his process; he evidently expected to have succeeded in using this fuel by the only mode of blowing a furnace then known, that by cold blast. Another patent was taken out about twenty years afterwards, for a mode of forming a conglomerate coke, composed of the comminuted substance of the anthracite veins, locally called culm, mixed with a sufficient portion of the small coal of the ordinary bituminous or binding quality, to cement the whole, when coked, in an oven together. Had this latter plan been attended with success, its application would, of course, have been limited to those localities where the two descriptions of coal were to be found near each other.

The Ynyscedwin iron works, which are in Mr. Crane's possession, are placed upon the anthracite formation. Until he discovered the method of applying this particular description of fuel to the smelting of iron ore, he was obliged to employ the coal of the bituminous veins, obtained from the adjoining parish of Kilybebyll, for the supply of the blast furnaces at Ynyscedwin.

During the fourteen years in which Mr. Crane has been engaged in the iron trade of South Wales, he has had his attention anxiously directed to the application of anthracite coal to smelting purposes, and had at different periods, at a large outlay, tried a variety of plans, but without success, until the idea occurred to him, that a hot or heated blast, upon the principle of Mr. Neilson's patent, might, by its greater power, enable him to complete the combustion of this very peculiar coal.

By this means he has completely succeeded in the application of anthracite coal to the smelting of ironstone and ore;—having used no other fuel in a cupola blast furnace since the 7th February, 1837; and the success of the experiment in the combination of hot or heated air with the coal in question, has been, in every respect, of so satisfactory a description, whether with regard to the quantity of the iron produced, the quality of such iron, or the economy of the process, that he is now actively engaged in making the necessary preparations for the introduction of anthracite coal, instead of the coke of the bituminous veins, upon the whole of the blast furnaces (three in number) at the Ynyscedwin iron works; he has renewed all his mineral takings in the anthracite part of the basin for ninety-nine years, and contemplates arrangements for a large extension of the works. Mr. Crane observes:

"One of the three furnaces at present on the establishment is a small cupola furnace, which we call No. 2, built from the top of the hearth with firebricks only. This cupola is of the following dimensions:—41 feet in its whole height, $10\frac{1}{2}$ feet across the boshes, and the walls of the thickness of two 9-inch bricks; the earth 3 feet 6 inches square, and 5 feet deep. The two other furnaces, which we call No. 1 and No. 3, are thick stone-walled furnaces. Some years since I found that the cupola furnace, No. 2, had, on the average of a long period, (I concluded from the smallness of its dimensions, and the thinness of its walls,) taken so large an excess of minerals to the ton of iron produced, when compared with the quantity taken on the average of the same period by the stone-walled furnace, No. 1, standing within fifty feet of it, that I determined to erect a second furnace similar to the latter one, in lieu of it. This cupola furnace, No. 2, not being at work when I arrived at the determination to try the experiment of the combination of hot blast and anthracite coal upon the large scale, it was more convenient to put this furnace into blast for the purpose, rather than to interfere with the usual progress of my business by experimentalizing in either of the two other furnaces.

"The cupola furnace, No. 2, from the causes which I have before explained, had, on the average of a long period, taken cokes the produce of 5 tons 3 cwt. of coal to the ton of pig iron, when the stone-walled furnaces had not required cokes to the ton of metal produced quite equal to four tons of coal. The consumption of ironstone and limestone had been greater in the former than in the latter description of furnace, but not in so large a proportion.

"I will make one other explanatory remark on this part of the subject. The two descriptions of furnaces have worked in so different a manner with the minerals of my neighbourhood, that, whilst the barrow of cokes, weighing about $3\frac{1}{2}$ cwt., would take, when consumed in either of the stone-walled furnaces, a charge or burden of 5 to $5\frac{1}{2}$ cwt. of calcined iron mine of the descriptions obtained in my neighbourhood, according to the kind of iron which I was desirous of producing, the same barrow of cokes in the No. 2 cupola, or thin-walled furnace, would only carry from 3 to $3\frac{1}{2}$ cwt. of calcined mine

of the same kinds. Under these disadvantageous circumstances, I have actually produced from the No. 2 cupola furnace the ton of iron in the smelting process, on the average of three months, with less than 27 cwt. of anthracite coal. The heating of the blast and the calcination of the mine require, of course, upon my plan, the same quantity of fuel which is necessary for the like processes in other establishments.

"With regard to the quantity of iron produced, the result which I have to report is equally satisfactory. I must not, however, omit to mention, that, for the greater convenience of filling this cupola furnace, No. 2, from an adjacent gallery, previous to the commencement of my anthracite experiment, I raised it in height from 36 feet 6 inches to 41 feet. This might have had *some* effect upon reducing the excess of the consumption of fuel when compared with that which had taken place in the No. 1, and might have increased its power of smelting with my blast of a $1\frac{1}{4}$lb. upon the square inch pressure only, from its former average of 22 tons to 24. Since I have adopted the use of anthracite coal, combined with hot air, the produce of No. 2 cupola furnace, with the same pressure of blast only, has ranged from 30 to 34 and 36 tons, and one week we actually tapped within 3 cwt. of 39 tons of grey iron from this furnace. Its present weekly average may be expected to range from 35 to 36 tons.

"With respect to the quality of the iron produced by the combination of hot blast and anthracite coal, the result is very satisfactory. It is well known in my neighbourhood, that my cold blast iron, for all purposes where great strength was required, was never deemed inferior to any smelted in South Wales. That which I have hitherto produced with hot blast and anthracite coal is, however, decidedly stronger than any other before smelted at the Ynyscedwin iron-works."

The anthracite formation probably occupies about one-third of the mineral basin of South Wales. It commences near the upper part of the Vale of Neath, in the county of Glamorgan, and proceeds in a westwardly direction through the remainder of that county; thence through Carmarthenshire, and crops out in the sea in St. Bride's Bay, after passing through a considerable portion of the county of Pembroke. It is likewise to be found in Ireland, Scotland, France, Austria, Bohemia, and Sardinia, and very large deposits of it have been already discovered on the continent of America, particularly in the state of Pennsylvania.

On Safety Lights for Mines. By Dr. ARNOTT.

The writer of this having had his attention called to the objects sought to be accomplished by the Davy Lamp, as related to the general subject of ventilating and warming, which he has treated elsewhere, conceived that perfect security against explosions in mines was obtainable in a very simple way, but on a principle differing entirely from what has directed previous attempts. This is to have the lamps

or candles in the mine supplied with air for combustion, not from the mine itself, as heretofore, but through pipes from the atmosphere above, as coal-gas is supplied through pipes to our street lamps.

At the mouth of mines generally, there is a steam-engine at work, part of the duty of which is, whenever required, to pump atmospheric air into the mine for ventilation; and a small portion of this air, sent unmixed to the lamps through a pipe of the cheapest material and construction, (of plank, for instance, with the seams pitched,) nailed along the galleries or cuttings of the mine, would effect the desired purpose. At the top or beginning of the air-pipe there would be a small gas-holder, of the usual construction, to receive air from the pump, and which would be nicely balanced, so that the propelling pressure might be accurately determined. That pressure would then be transmitted along the tube, so that at any opening there would be a steady outward rush of pure atmospheric air, as there is a rush of coal-gas from any opening in common gas apparatus. A common lantern, therefore, with glass front and sides, well secured, if screwed on or otherwise attached at such opening, would be always supplied with atmospheric air; and if there were no further opening in the lantern except the small chimney opening defended by a length of tube, with a valve at the extremity if desired, there could be no communication between the flame and the air of the mine. If further security were desired, both openings might have the wire-gauze of Davy's Lamp stretched across them.

For fixed lights with such apparatus, it would be necessary only to screw fit lanterns to the air-pipe in required situations, and lamps affording very strong light might be used.

For lights moveable within a certain distance, there would be lanterns connected with the air-pipe by flexible tubes of covered spiral wire.

For lights moveable or portable to all distances, there would be either large lanterns, which, once filled with pure air, would feed the light for half an hour or more before it became too dim, or there would be lanterns of ordinary size, having attached to them bags of thin cloth rendered air-tight by caoutchouc or otherwise, which bags would be filled from time to time with atmospheric air from openings in the main air-pipe.

All along the main-pipe there would be means of fixing lanterns, and of taking pure air for any purpose.

There might be, at convenient stations in the mine, boxes or small chambers communicating with the air-pipe, and, therefore, always full of pure air, in which the operations of striking a light, lighting lamps, and others, (as cooking even,) might be performed.

Lamps might be lighted by a lucifer-match suitably introduced and inflamed, or there might be a small *lighting lantern*, between which and any other a communication might be opened for a lighted taper to pass to the wick to be lighted.

The expense of such an apparatus as here contemplated would be

trifling compared with the importance of the object sought, and, with a certain expense, the security might be rendered very complete.

On the Waste experienced by Hot and Cold Blast Iron during the process of Refining. Communicated by D. MUSHET.

On Preventing the Corrosion of Cast and Wrought Iron immersed in Salt Water. By J. B. HARTLEY.

The author observes, "The well-known powerful and mischievous effects of salt water upon iron having been very strongly felt in the various fastenings of the gates and other machinery of the Liverpool Docks subjected to its action; and as a counteraction of this evil has long been a desirable object, many experiments having been made with this view, but in a great measure without success; and since the same destructive tendency is more or less experienced in all similar cases, the following very brief account of the method at present employed to obviate it by my father (the Engineer to the Docks), together with the circumstances which gave rise to his adoption of it, may not be deemed uninteresting.

"In order to afford a greater extent of dock space to the fast increasing trade of this port, the Liverpool Dock Trustees, in 1829, purchased a quantity of land at the south end of the town, a part of which was occupied by an old tide mill and basins, called 'Jackson's Mill and Dams;' in taking away these dams for the purpose of forming the present Brunswick Dock, in the beginning of the year 1830, an old *cast-iron sluice* or *clow* was met with, the mouth of which was fitted with a lid or valve, also of *cast iron,* and of considerable dimensions: these had been immersed in the *salt water* for rather more than 25 years, having been put down, as found from good authority, in 1804. When taken up, they were incrusted with a coat of small barnacle shells, and, when broken, some parts of the *cast iron* were found to be in excellent preservation, and some thoroughly decomposed. The *cast iron* lid or valve was fastened to the body of the sluice by means of *brass pins,* $2\frac{1}{4}$ inches in diameter, forming hinges on which it turned, when lifted up or lowered, as occasion required; and *immediately in connection with these pins* it was that the iron was in a *perfectly sound state.* By some inadvertency all the iron-work was broken up, and sent with other old metal to the furnace.

"In July of the same year (1830), another sluice, with a similar valve, was taken up, which had been immersed in *salt water* for the same length of time; this was also of *cast iron,* but the lid or valve had, in addition, a loop cast on to its lower edge, with which it was opened and shut by means of a connecting rod. The top joint or hinge of the valve was similar to the one previously found, that is, turning on *brass pins,* which worked in *iron* collars cast on to the body of the sluice;

the lower joint or loop was *bushed* with *brass*, through which a large *wrought-iron* pin passed, forming the joint between the connecting rod and the valve.

"All the parts of the *iron* immediately around the *brass* were in this, as in the former case, in *excellent preservation*; the *wrought-iron* pin was corroded a little, but not materially; yet, had it been suspended in a similar manner by itself, or in connection with iron stone, there can be little doubt but that it would have been, in a great measure, if not wholly, destroyed. The cast iron near to the brass retains its original soundness, but became gradually *decomposed* in proportion to its distance from the protecting influence.

"The action of the salt water upon iron at this port is exceedingly great, causing a very rapid corrosion; work similar to what has been described, but in which no brass has been used, having been taken up as useless after a service of only eight years; the cast-iron becoming so decomposed as to yield easily, like plumbago, to the penknife, and the wrought iron wasting away to a mere thread; much, however, in both cases depending upon the quality of the iron.

"The hint thus fortunately received has, therefore, since been taken advantage of, and acted upon as much as possible by my father in all our recent works. The dock-gates, which, heretofore, have been greatly affected, are now in a great measure protected by using *brass* with *iron* whenever it can properly be done. Copper fastenings are no longer used, *iron bolts* with *brass nuts* and *washers* having been substituted: the sills, which are made of *cast iron*, have numerous small holes bored through them, which are again filled up with melted brass; the chain-hole rollers, also of cast iron, are keyed on to metallic shafts, turning in cast-iron steps, and in all cases where strength and durability are most required, the iron in these parts is thus protected. So far as five years' experience can testify, perfect success has been the result. The *wrought-iron* bolts are now as perfect as when first put and the cast iron shows no symptoms of decay. A proof of this may be seen at the outer gates of the Brunswick Basin, which were fastened and finished as described, and have been now in use upwards of five years."

On Browning Gun Barrels. By W. Ettrick.

On a Method of Facilitating the Calculations of Gases. By Dr. Clarke.

On some Singular Modifications of the Ordinary Action of Nitric Acid on certain Metals. By Dr. Andrews.

On an Antimonial Compound applicable as a Pigment.
By Dr. TRAILL.

It is made by adding a solution of ferrocyanide of potassium to the muriate of antimony. The precipitate, which is of an ultramarine colour, Dr. Traill considers to be composed of prussic acid, iron, and oxide of antimony.

On the non-production of Carbonic Acid by Plants growing in the Atmosphere. By DR. DALTON.

Dr. Dalton calculates, that in 5000 years, animals supposed to live upon the earth, would produce by their breathing in the atmosphere but $\frac{1}{1000}$ part by weight of carbonic acid, therefore the assistance of plants to purify the air is not necessary. By experiment he found, that a hot-house does not contain more or less carbonic acid, by night or by day, than the external air, and the results were the same in a number of repetitions of the experiments. This paper was said to have been penned during the convalescence of its illustrious author from a late attack of illness.

On the Action of Water upon Lead. By T. J. PEARSALL.

On a New Form of Iron Bottle for obtaining Oxygen from Peroxide of Manganese. By Mr. J. DICK, *of Cambridge.*

Mr. Griffin exhibited chemical apparatus adapted for experiments on a small scale.

Mr. J. Murray presented to the Section a phial of the milk of the Cow-tree, with an account of its chemical and other properties; also, specimens of two sorts of paper manufactured from the phormium tenax and the musa textilis.

On the Influence of Electricity on the Process of Brewing.
By W. BLACK.

According to the author's statements, a thunder-storm not only checks the fermentation of worts, but even raises the gravity of the saccharine fluid, and developes in it an acid. This effect is principally witnessed when the fermenting tun is sunk in moist earth, and may be obviated by placing it upon baked wooden bearers, resting upon dry bricks or wooden piers, so as to effect its insulation. Mr. Black also stated, that during the prevalence of highly-electrified clouds, the fabrication of cast iron does not succeed so well as in other states of the atmosphere.

GEOLOGY.

Mr. Whewell reported from the Committee appointed to determine the best means of ascertaining the degree of permanency of the relative levels of land and sea. He stated that Mr. Bunt of Bristol had been engaged to effect the first operations towards this object; that he levelled a preparatory line from Bristol to Portishead (a distance of 10 miles), which proving satisfactory to the Committee, he was subsequently directed to procure the necessary instruments, and to level a line from Bridgewater to Axmouth. The course followed was as follows: From Bridgewater, near the north bank of the river Parrott, to Langport; then crossing the Parrott by the Vale of the Isle, and proceeding 11 miles, the town of Ilminster was left one mile on the left, and the levelling carried to the top of the Hill of Chard, which is 300 feet high, and the only hill encountered; descending to the south, the Vale of the Axe was followed to the sea, the whole distance being 40 miles. The levellings were twice repeated (once forwards, once backwards), and the difference of the two results was only $3\frac{9}{10}$ inches; but as, in the greatest part of the distance, the difference increased almost uniformly in going southward, the error was probably due to some steady cause, and, consequently, the mean of the two results may be considered as very near the truth. The precise cause of the error has not yet been ascertained, but as the instruments are the property of the Association, they can be examined at any future time. Good referring-marks have been left to afford means of repeating and extending the levels, so as to make any future comparison of the state of the levels with those now ascertained, that being the object of the investigation.

The results of this survey for level cannot be stated until it has been continued to the Bristol Channel.

A Notice of Specimens containing Fossil Vegetables, from the New Red Sandstone at Stanford and Ombersley, in Worcestershire. By JAMES YATES, *F.L. & G.S.*

Mr. Yates stated, that his object in bringing forward this notice was principally to induce others to work out the hint he was giving. In the N.W. angle of Worcestershire, the new red sandstone is in immediate contiguity with rocks of the Silurian System, and appears to assume some of the characters of the German keuper. The sandstone of Stoneyedge Quarry, in the parish of Stanford, is greenish, finely granular, and schistose, resembling the fine flagstones of the coal formation. It contains vegetable impressions resembling those of the coal. It has been used for building, and is remarkably durable, when laid with its strata horizontal. To determine the geological position of this sandstone, Mr. Yates traced it for ten miles,—by Martley, Ham-

bridge, Hood Martin, and Clifton on Teme, to Stanford. At Martley, it exhibited the usual appearance of the new red sandstone of Worcestershire and the adjacent counties. Then, on proceeding, it was frequently micaceous and slaty, and exhibited numerous variations of colour, until, without any other important change, it was traced to the beautiful building-stone of Stanford, where, in descending order, it is succeeded by strata of limestone belonging to the Ludlow Rocks of Mr. Murchison. In the quarries of Ombersley, the sandstone is white, inclining to green or grey, and much resembles the sandstones of a coal formation, though all the surrounding strata have the usual colour and appearance of the new red sandstone. In these quarries, vegetable remains are very abundant, amongst which may be distinguished calamites, the fossils generally resembling coal plants. Stems or boughs, apparently of coniferæ, are cut across in working the quarry. The wood is in part converted into coal, and in part preserves indistinctly its vascular structure. The stems contain a considerable quantity of oxide of iron, and around them the stone is rendered ferruginous. Mr. Yates left the decision of the question—whether these sandstones belonged or not to the keuper, to those geologists who had studied that formation on the Continent: he was himself inclined to decide in the affirmative. Mr. Yates then stated his opinion, that the whole of the new red sandstone of England must either have been part of the bed and estuary of a river, or, if a marine deposit, have been formed so near the dry land as to be under the influence of currents sweeping along the shore. The portions he had described must have been, he considered, the margin of such river or sea, the Silurian Rocks having formed its banks. Mr. Yates concluded by exhibiting a specimen from Brockhill Quarry, in the parish of Shelsley Beauchamp. A trap-dyke passes there vertically through the slates and fine sandstones of the Silurian System, and converts them into a substance not distinguishable from the trap, except by stratification; a phenomenon which Mr. Yates had also observed in the Duchy of Nassau. The specimen,—part of these altered stratified rocks,—was further remarkable, as exhibiting in the coatings of its sides brilliant crystals of chabasie.

The Rev. Mr. Clarke requested permission to read two letters which he had received from Professor Hitchcock of Amherst, Massachusetts, on the subject of foot impressions, supposed to be those of birds, on a rock which the Professor refers to the new red sandstone. The first, dated March 1, 1837, states, that in the examination of some new localities, the author had extended the number of species, recognizable by the footmarks, from seven to twenty-one, some of which are very remarkable, and approximate to a sauroid type. One of these footmarks is fourteen inches long, has a heel larger than that of a man, and a fourth toe coming out at right angles near its extremity. The length of the step is four feet. Professor Hitchcock adds, that he has found on the greywacke of Hudson River what he thinks the footmarks of a marsupial quadruped, or of a quadruped that moved forward by leaps. They are not, however, so distinct as the marks on the new red sand-

stone. Professor Hitchcock then proposes for such footmarks the following classification. Class, Ichnites:

1st Family—Tetrapodichnites.
2nd Family—Sauroidichnites.
3rd Family—Ornithichnites.

In the second letter, dated May 9, 1837, Professor Hitchcock announces his having forwarded to Mr. Clarke between thirty-five and forty specimens (some of the rock itself, and others casts) of the footmarks. He states the number of species found since his first publication to be fifteen, making the total number 22. Mr. Clarke then exhibited to the Section several of the specimens.

On the Nature and Origin of the various kinds of Transported Gravel, occurring in England. By HUGH E. STRICKLAND, *F.G.S.*

On examining the masses of drifted materials, which, in patches of gravel, sand, or clay, cover a considerable portion of the surface of the island, Mr. Strickland perceived remarkable distinctions of character. Taking the varieties of rocks present as a clew to the direction of the forces which have moved them along, it appeared that in some cases the pebbles and boulders were derived from the immediate vicinity; in others, that they had probably travelled many hundreds of miles. The beds were sometimes wholly unstratified, and at other times finely laminated, indicating a violent or tranquil state of the transporting medium. Some varieties of drift occupy the summits of hills, and are independent of the present configuration of the surface; whilst others occur on the sides or bottoms of valleys, having a constant relation to the present lines of drainage. And again, some gravel beds contain remains of mammalia and lacustrine mollusca,—others contain only marine remains; and a large portion appears to be destitute of organic remains. Such varied results seem to indicate a variety of causes, distinct in kind, and operating at separate epochs; but as all these varieties of detritus are unconformable to the rocks on which they rest, and from lying in detached portions are seldom brought in contact with each other, it is very difficult to determine their respective ages, or to establish the precise number of distinct epochs at which they may have been formed. Evidence, however, of two periods may be clearly obtained; and Mr. Strickland proposes to call the matter deposited in the first period a *marine drift*, being the result of submarine currents at a time when the central portions of England were under the ocean; and that deposited in the second, *fluviatile drift*, having apparently been deposited by ancient rivers (or river-lakes) at a time when the whole or a great part of England had become dry land. The gravel which covers the midland counties, from Cheshire to Gloucestershire, has resulted (as proved by Mr. Murchison from the evidence of marine shells) from a marine current flowing from the North, between the oolitic hills of England, and the

older rocks of Herefordshire and Wales; and hence, at that period, the whole island must have been many hundred feet lower than it is at present,—nay, it may have been totally submerged, as the absence of erratic gravel on the oolite hills, and on the mountains of Wales and Herefordshire, does not necessarily imply that those districts were dry land when the gravel was drifted into the midland counties, since the erratic pebbles would necessarily be directed towards the lowest levels, and districts out of the exact line of the current might even be in course of local degradation whilst the extraneous matter was hurried past them. The probability that the chalk and oolite hills of England were principally, if not entirely, submerged, is strengthened by the fact that ramifications from the general mass of gravel in Warwickshire extend through the transverse valleys of the oolitic range, follow the course of the Thames, and cross considerable hills near Oxford and Henley, as shown by Dr. Buckland. As the marine shells found in this gravel are chiefly of existing species, a very recent epoch must be assigned to its deposition; and as no traces have been left of regular tertiary strata, even in small valleys and basins sheltered from the action of the northern current, it seems probable that the causes which led to the transport of the gravel were comparatively transient. The most reasonable supposition appears to be that this transport was connected with the elevation of the land, the new red sandstone of central England having been covered up by younger deposits, when a process of elevation and of accompanying denudation commenced, whereby the upper secondary strata were removed, and the new red sandstone exposed to the action of the marine currents. And when, by a further rise, England was elevated above the sea level, the midland counties would present an undulating surface of new red sandstone and other rocks, with scattered patches of erratic gravel, the relics of the action of denuding currents. But whether the northerly current which has effected such devastation was the direct result of elevation of the land, and consequently transient and violent, or whether it was similar to ordinary marine currents, such as that now flowing through the Pentland Firth, it would be premature to speculate.

These marine detritic deposits consist of gravel, sand, or clay, in varying proportions. The gravel contains numerous pebbles of white or brown quartz, mixed more or less with other substances. It is in general very imperfectly, or not at all stratified, there being some local exceptions to the rule. It is believed that no mammiferous remains occur in this drift, the only genuine fossils being marine shells, which have been found in some few localities in Cheshire, Shropshire, Staffordshire, and Worcestershire. And it is remarkable that it occurs independently of the minor variations of the surface, covering extensive tracts, and capping hills of 400 or 500 feet in height.

There are three principal varieties of marine drift; 1st. erratic gravel without chalk flints; 2nd. erratic gravel with chalk flints; and 3rd. local or non-erratic gravel. The gravel without chalk flints covers the country to the North and West of the Warwickshire Avon.

The gravel with flints occurs chiefly between that river and the foot of the oolite hills. The chalk flints indicate an easterly current. The gravel without flints came from the North; but as no section has yet shown a superposition of one of these beds of gravel on the other, so as to prove a different epoch of formation, they must at present be ascribed to one, and the difference of direction in the currents attributed to the obstacles they encountered in their passage; for instance, a current flowing to the S. or S.E. through the counties of Nottingham, Leicester, and Northampton, would, on encountering the chalk hills of Huntingdonshire, be turned to the westward, and carry chalk flints into Warwickshire, mixing them with the quartz and other northern pebbles, whilst the western part of the same current would flow uninterruptedly through Staffordshire and North Warwickshire, depositing pebbles of northern origin in its way, and finally make its exit into the Bristol Channel. The third variety, called local drift, as being derived from rocks of its immediate vicinity, occurs in patches along the base of the oolite escarpment in Warwickshire, Worcestershire, and Gloucestershire. And as the evidence of superposition is here also wanting, the local and erratic drift cannot be ascribed to different epochs, but must be assumed as modifications in the effects of the same great cause; for it is very possible to conceive that whilst pebbles from a great distance were moving along the central and lower parts, local shingle beaches might have been forming (composed entirely of the rocks there suffering degradation) at points more out of the line and influence of the current, just as is the case in rivers, the margins of which are often skirted by the detritus of its banks, whilst their beds are occupied by pebbles washed from a distance. The local drift of Siluria has been shown by Mr. Murchison to be overlaid by the northern or erratic drift near Shewsbury, and is therefore referred by him to an antecedent epoch.

The marine drift seems to have been deposited when a large portion of England was under water; the next class, or fluviatile, when much of it had become dry land. In materials the marine and fluviatile are the same, and are hence easily confounded together; but they occupy different positions, and contain different organic remains. The fluviatile drifts bear a constant relation to the present form of the surface, and are commonly found flanking the sides, or covering the bottoms of valleys, often at a definite elevation above the present drainage: in general they are in a finer state of lamination, which proves a more tranquil deposition. They contain mammalian remains, and freshwater shells of existing species are sometimes found with bones of extinct land animals; indeed it is probable that such shells will be found to be generally diffused through them. On the Warwickshire Avon, platforms of gravel, containing bones and freshwater shells, may be traced at intervals down the valley, from Rugby to Tewkesbury, at heights from 10 to 50 feet above the present stream; and these platforms are strongly contrasted with the marine drift which caps the hills flanking the river, both as respects the mineral character of the gravel, and the absence of stratification and

mammalian remains in the marine drift. No absolute junction of these gravels has yet been noticed, though they occur within a quarter of a mile of each other, at, as already stated, very different elevations—the marine drift being highest, as a portion of the great deposit formed prior to the elevation which gave rise to the river or chain of lakes which formed the fluviatile drift.

Mr. Strickland then stated the following as his own conclusions from the data he had collected or studied—namely,

1st. That the great mass of erratic gravel which exists in England has been brought by a northerly current, at a time when all, or the chief part of England, was under the sea, and contains no terrestrial fossil remains.

2nd. That bones of terrestrial mammalia are only found in the deposits of ancient rivers or lakes, formed after England had been raised above the sea, and had nearly assumed its present form.

Mr. Strickland concluded by suggesting to Geologists the necessity and importance of collecting data for solving the intricate question of the origin of gravel deposits, such as the varieties of rocks found in each deposit, the mode of its arrangement, the presence and kind of fossils contained in each, the elevation at which they are respectively found, and the relations they seem to have to the existing surface.

On the Mechanism of the Movement of Glaciers. By ROBERT MALLET, *M.R.I.A.*

After briefly alluding to the peculiar appearances of glaciers, and their vast extent, equal in some cases to the area of a small English county, Mr. Mallet observed that, notwithstanding the labours of Merian, Höttinger, Simler, Scheuchzer, Grünen and Saussure, the forces which give rise to their motions, modify their forms, and lead to their increase or decrease, have been overlooked. To supply this defect fully would be beyond the limits of a single paper, and Mr. Mallet therefore confined himself to the consideration of those forces which caused the descending or precessional motion of glaciers, of the causes of the vast rifts or crevices which traverse them, and of the peculiar arrangement of the moraine or stony debris which covers large tracts of their icy surface. Hitherto writers (Saussure, Playfair, etc.) had ascribed their descent to the action partly of the weight of the glacier itself and partly of that of the vast masses of snow resting upon it, which together, had driven the glacier gradually forward, on the inclined plane upon which it rested; and this explanation had been adopted and repeated by later writers, including Dr. Prout in his Bridgewater Treatise. This view Mr. Mallet considers inadequate to explain the progressive movement, sometimes as much as 25 feet in a year, since the supporting surfaces of rock are always deeply rugged and hence afford a great resistance in friction; and further that the inclination of the

beds of the glaciers does not exceed 25°, or of the supereminent plane of the snow above 35° to 40°; so that the portion of the weight resolved on mechanical principles in a direction parallel to the inclined plane, or in the direction of motion, would be extremely small. Weight alone, therefore, or pressure from it being inadequate, Mr. Mallet ascribes the movement to the hydrostatic pressure of water accumulating between the masses of ice and the rocky bed on which they rest, whereby the ice is as it were floated or transferred (at intervals) upon liquid rollers from a higher to a lower level. From the nature of the isogeothermal curves, the bed on which the glacier rests is warmer than the glacier itself, hence a continued melting of the lower surface, and a constant production of torrents which rush out at the lower extremity of every glacier. This melting is independent of season, whilst the melting of the superficial snow and of the external surface of ice depends solely upon it; hence in summer there is no obstruction to the flowing of the torrents, whilst in winter their embouchures are closed by ice, and an accumulation of water below is the result, by the pressure of which the glacier is raised until a sufficient vent has been formed for the escape of the waters, on the sinking of which the glacier descends for a certain distance into the valley. An example of a striking kind occurred in 1814-1815, in the Glacier de Bois, or the "Mer de Glace". Its torrent, the Aveyron, being dammed up by the falling masses of ice, and partly frozen, could no longer discharge itself at its usual icy opening, but accumulated under the ice until it forced itself a new passage, 700 feet above the former one; the pressure being so great that for some months mountains of ice were continually falling. In short, the ice is by this hydrostatic pressure raised up perpendicularly to the inclined plane on which it rests; but, on the removal of the pressure, sinks perpendicularly to the horizon, and hence advances forwards. Next, with respect to the rifts or crevices which intersect the glaciers, they have, allowing for slight perturbations depending on the steepness of the slope of the beds, a general direction transverse to the line of motion, or across the valley in which the glacier lies, and the form of a curve or vast wave-like line crossing the ice from side to side, and having its convex side downwards. The glacier itself may be considered as a bed of indurated snow, deposited at the bottom of a sloping valley, and surcharged with infiltrated water, either the result of rain or its own slow liquefaction, and must be presumed therefore to have originally formed one unbroken mass, beneath which flowed a current of ice-water. But whenever this stream became obstructed either by frost or debris, the water would begin to rise beneath, until the hydrostatic pressure at the lower end becoming sufficient to overcome the cohesion of the ice, the huge mass would be broken in two or more parts, somewhere above the upper line of the subglacial waters, just as a stranded vessel, supported at stern and stern, becomes, in technical language, hogged. And according as this process is modified by the accidental staggering of one mass against another, &c., so is the aspect of the whole strangely and capriciously varied. Sometimes an isolated rock resting on the surface, melts, from its superior conducting power,

the ice on which it rests, and sinks down, forming in the substance of the ice a tube of an enormous depth; one found by Mr. Mallet in 1831 having a depth of 70 feet and a diameter of 3 feet. This tube gradually enlarges and becomes filled with water, until the pressure of the column of water overcomes the lateral cohesion and splits the mass into two or more pieces.—The curvilinear form of the crevice is next explained. As the waters proceeding from the melting of the under surface of the ice will coalesce towards the centre of the bed of the glacier, or the lowest point of its sloping surface, so will the centre be raised more and descend more than the sides; and, in consequence, the central part of the whole crevice descending most, it becomes convex downwards.

Mr. Mallet then entered on a discussion of those accumulations of stony debris called "Moraine," which are to be found on all the glaciers, and most remarkably on the glacier of Rosboden on the Simplon. These are ridges of loose materials arranged parallel to the motion of the glacier, or across the ice crevices. The detritus proceeding from the precipices which flank the glacier valley is continually falling and mixing the snow with gravel and rocks; and, as the summer heat melts the winter snow, all this suspended matter sinks down to the surface of the ice, and by the force of torrents sweeping over the ice is formed into those ridges which lie nearly parallel to the line of motion of the whole glacier. In these ridges, the centre is many feet deep; and as this thickness protects the ice below from the heat of summer, an elevated wall of ice is formed, the uncovered snow on each side being melted down, so that these ridges of stones stand upon hills of ice sometimes 25 feet above the general surface; and as the centre of the glacier sinks more than the sides, these hills have a natural tendency to topple over and discharge their load of stony matter towards the centre: hence the greatest deposits of moraine are nearest the axis of the whole glacier, and these act as checks to its too rapid melting, without which it is probable some of the greater glaciers would have been entirely melted through, and the mechanism of their motion destroyed. On the principles here laid down, the motion of the glaciers is most rapid after a severe winter, and *vice versâ*. The constant descent of a glacier over its bed must abrade and smooth the surface of the rock, just as if it had been the bed of a torrent; and it may therefore be possible to trace in such marks the former existence of glaciers now totally melted away.

On the Results of Trials which had been made for Water in the Desert between Suez and Cairo. By Marquis SPINETO.

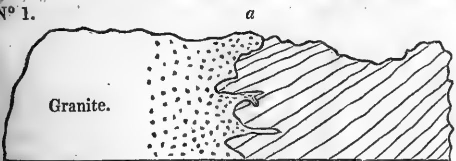
This search had been conducted by M. Albert Gingbery, an engineer and mineralogist, and had proved successful, five wells having now been established on that route. In these trials the water was found at the depth of 14 feet, filtering through a calcareous rock, and in a stratum of clay or marl. The results of several other borings

for water were also detailed: in these the depths at which water was found are very variable—namely, 237 feet, 299 feet, 86 feet, 60 feet, 58 feet, and the alternations of sand, clay, siliceous rock (called by the author Jasper), exhibit at short distances considerable irregularity.

On certain Phænomena connected with the Junction of Granitic and Transition Rocks, near Christiania in Norway. *By* CHARLES LYELL, *F.R.S.* (communicated by L. HORNER, *F.R.S.*)

It has been long known by geologists that granite occurs in the neighbourhood of Christiania in Norway more modern than the schist and limestone, containing trilobites, orthocerata, and other fossils of the transition period. It is also, I believe, the prevailing opinion that this granite offers an exception to the general rule, and that it covers the fossiliferous formations in large overlying masses, in the same manner as is commonly the case with basalt, and other members of the trap family. I found, however, on visiting this summer with Professor Keilhau several points where the junction of the granite and transition strata is well seen, that the phænomena agree precisely with those usually exhibited where granite comes in contact with other rocks, and sends veins into them. M. Keilhau had already come to this conclusion, after examining the whole line of contact of the granite and fossiliferous beds, and in this respect my observations went no further than to verify and confirm his statements. It is true that in some places near Christiania the granite may lean somewhat over the edges of the transition beds, and be for several yards incumbent on them (as at *a*. No. 1); but not by any means so as to resemble the overflowing trap rocks. Nor was it from such appearances that the overlying position of the Christiania granite was first inferred, but rather from the manner in which the strata of schist and limestone frequently dip towards the granite up to the point of contact, appearing as if they would pass under it. (See No. 1.) When, however, these strata are traced up to the granite, they are seen to terminate abruptly; and no instance is known to Professor Keilhau, in this country, of a large mass of granite regularly overlying strata containing organic remains.

Nº 1.



The different varieties of granite in this part of Norway have been described by Hausmann, Von Buch, and others. They are chiefly syenitic, but must all be classed by the geologist as granite, presenting the usual characters of that family of rocks both in small specimens and mountain masses. This syenitic granite seems to pass in some regions into trap porphyry, but it is only where the rocks have assumed

all the usual characters and aspect of trap that tabular masses are seen distinctly overlying the fossiliferous strata.

The important fact of the comparatively modern origin of this granite, or of its posteriority in date to the strata containing orthocerata and trilobites, was announced by Von Buch about 25 years ago. The proofs consist in the protrusion of granite veins into the schist and limestone, and the alteration of the fossiliferous strata to a considerable distance from the line of contact with the granite, the limestone being turned into white marble, and the schist into Lydian stone, riband jasper, and sometimes into mica-schist, of which I saw one striking example at Grorud, N.E. of Christiania. Traces of fossils are not unfrequently discoverable in some of the crystalline and altered rocks of the transition formation, so that the actual conversion of the latter into metamorphic strata is unequivocal.

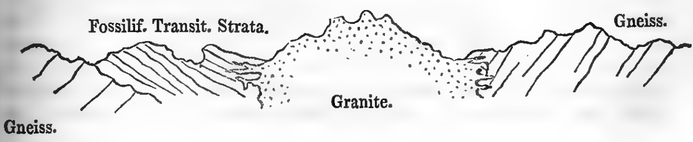
Large mountain masses of the granite come into contact with different members of the transition series, both calcareous and argillaceous, and the granite sends veins into all of them, and variously modifies their mineralogical texture. The fossiliferous strata are also seen intersected by the granite, sometimes in the direction of their strike, and sometimes at right angles to it; the stratified rocks being in all cases more or less changed at the point of junction. The same modern granite comes frequently into contact with gneiss, the most ancient formation of this district, and sends veins into the gneiss, or, in some cases, passes gradually into it, precisely in the same manner as in Scotland and other countries.

There is, indeed, no feature in the geology of this part of Norway which appears to me so full of interest, as the relations of the granite and gneiss at their junction, when the wide difference of epoch which must have separated the origin of the two rocks is considered. I shall therefore add a few words on this subject.

The gneiss is the oldest rock in the country. Next in age are the transition strata, corresponding to part of the Silurian formations of England; but as these fossiliferous strata rest unconformably upon the gneiss, the last-mentioned rock had evidently undergone great disturbances before the sedimentary deposits were gradually thrown down upon it. The edges, moreover, of the inclined strata of gneiss had undergone aqueous denudation, and had been polished and scored by attrition before the unconformable transition beds were superimposed. This scored and polished surface is seen occasionally on the removal of the newer or fossiliferous beds. As the granite, therefore, was introduced last of all in the order of time, there had intervened between the origin of the gneiss and granite, 1st, the period when the stratification of the gneiss was disturbed, 2dly, the period of its denudation, and, 3dly, the time during which the transition beds were gradually formed in a sea inhabited by a great variety of organic beings. Yet the granite produced after this long interval is often so intimately blended with the ancient gneiss at the point of junction, that it is impossible to draw any other than an arbitrary line of separation between them; and where this is not the case, tortuous veins of granite pass

freely through gneiss, ending sometimes in threads, as if the older rock had offered no resistance to their passage. Had I seen such junctions alone, and known nothing of the relative age of the gneiss and granite, I should have been inclined to suppose that the gneiss had not yet been fully consolidated, and had not, perhaps, assumed its complete metamorphic character at the time when it was invaded by the granite; but this hypothesis is quite inadmissible, fragments of the gneiss having been imbedded in the transition strata long before the granite appeared. The only hypothesis, therefore, that seems to remain to those who adopt the Huttonian theory of granite is, to conceive the gneiss to have been softened, and more or less melted when the granite was introduced. I have before mentioned that the fossiliferous strata occasionally dip towards the granite up to the line of contact; and it deserves mention, as a singular phænomenon, and a general one near Christiania, that neither the strike nor prevailing dip of the transition beds is affected, or seen to vary at the points of union with the granite. They are altered in mineral character, as before described, and often become quite metamorphic; but they are not more disturbed there than elsewhere, and their inclination and bearing remain the same. What is still more extraordinary, there are places which I visited with Professor Keilhau, where portions of the transition beds, some of them only a few hundred yards square, occur completely isolated and surrounded by granite, and yet continue to preserve their normal dip and strike. This phænomenon has been adduced by Professor Keilhau as offering, together with many others in the same district, strong grounds of objection to the Huttonian theory; for it appears to him impossible that the granite can have been injected in a fluid state, or forced into the fossiliferous strata without causing more local derangement in their dip and strike.

Without denying the consideration due to this argument, I confess that its weight was much lessened in my mind after seeing other appearances exhibited in certain large dikes of syenite which pierce through the fossiliferous strata near Christiania. Some of these dikes scarcely differ from granite in texture, and are occasionally branched; yet the strata at the junction, or even when included between two ramifications of syenite, preserve their accustomed dip and strike. The analogy of such dikes to trappean and volcanic dikes, both in form and in their relations to the intersected strata, together with the occasional passage of the syenite into common greenstone, leave me in no doubt that they are masses and walls of fused matter which have filled up fissures opened in the previously consolidated transition strata.



On the Geology of Spain. By Dr. TRAILL.

In the sketch of the geology of the Spanish peninsula laid before the British Association in Dublin, the author gave a general view of its principal mountain chains, and a more particular account of the structure of Andalusia and New Castile. The basis of the mountains on the S.W. and N. of the latter is granite; which in the southern and western boundaries is directly covered by clay slate, and in the Guadarrama chain by gneiss and mica slate. In the Sierra Morena, the clay slate, reposing on the granite, strongly resembles the slate of Cumberland; and at Santa Elena, in the pass of the Sierra Morena, contains crystals of chiastolite. The primitive rocks of the central ridges of Spain are, on all sides, quickly succeeded by the old sandstone formations; on which we often find a very compact, greyish white limestone, with an imperfectly conchoidal fracture, which the author, from its geological relations, considers to belong to the Jurassic formation. This limestone is very widely distributed in the eastern provinces, from the mountains of Jaen and Granada to Gibraltar, and covers the flanks and peaks of the Sierra Nevada to the height of 9000 feet, the highest point he was able to reach in the end of May, on account of the state of the perennial snow which invests it for 2000 feet higher. This limestone is seen in the Sierra Carbonera, near Gibraltar, to rest upon old sandstone. Another limestone formation, of a more friable and gritty aspect, abounds on the flanks of the mountains, which he considers as the representative of the oolite of England. True chalk forms considerable tracks in Western Andalusia, especially near Lebrija; and considerable tertiary deposits occur in the plains and valleys south of the Sierra Morena.

In that portion of his paper read before the Geological Section in Liverpool, Dr. Traill described the northern part of New Castile, part of Aragon, and Cataluña, including the celebrated salt mine of Cardona.

The plains between Madrid, the Somosierra, and the mountains dividing Castile from Aragon, chiefly consist of vast beds of marl, gypsum, and sandstone, over which, in some places, lies a limestone, which he considers as oolitic. He traced these formations through Grajanejos and Maranchon to Uset, the first village in Aragon. At Uset they disappear, and their place is supplied by a quartzose sandstone, splitting into thin layers, which may be used as roofing flags, and contain many crinoidal remains. This sandstone appears to rest on a well-characterized greywacke slate, devoid of organic remains. This last rock is well seen at the pass named *Puerta de Daroca*, where it contains thin beds of a very pure quartzose sandstone flag; and these strata are seen dipping below the more common sandstone that occurs near Uset. In descending from this pass, the sandstone may be traced to the banks of the Rio Xiloca, where it is covered by a thick bed of coarse argillaceous conglomerate, forming stupendous cliffs, overhanging the city of Daroca and its narrow valley. Red marl and gypsum reappear in the wider parts of the

valley, and extend over the elevated plain to the north of that city. From the northern verge of this plain there is a gradual descent into the wide and fertile valley of the Ebro, where luxuriant vineyards and olive plantations cover a marly soil full of small gravel. The boundaries of this portion of the valley appear to be oolitic limestone, which forms flat hills, of a sterile aspect. Near Zaragoza, the rock below the soil, whenever it appears, is a yellowish grey limestone, which Dr. Traill refers to the same formation.

After crossing the Ebro at Zaragoza, the route to Fraga lies chiefly over a desolate plain, named *Llaña de Santa Lucia*, once under cultivation, but now abandoned to rosemary, thyme, and other aromatic plants on its higher portion, and only appearing green where water lodges in the hollows during the rainy season, and produces *salsola*, *salicornia*, and similar plants, which the peasantry cut and burn into barilla, in the months of September and October. The whole soil is gypseous and saline; the pools are brackish or absolutely salt; and potable water over this region is so scarce, that at Bujaralos it was sold at sixpence per gallon. At Peñalba the author found horizontal beds of a limestone containing fresh water shells; but the relative position of these beds become very apparent at the abrupt termination of the Llaña, in the valley of the Rio Cinca. There he observed an upper stratum of a greyish limestone, containing numerous fragments of limneæ and planorbes; then a second with fewer of these organic remains; both rested on beds of clay marl, containing thin strata of snow-white fibrous gypsum, and thick beds of the same substance in an earthy state. He did not detect any chalk in this place; but he found here nodules of pure flint. The whole of these strata covered a reddish sandstone, which is exposed in the bed of the Cinca. These limestone beds he considers as tertiary; and he traced similar formations to the other bank of the river, beyond the city of Fraga. The whole of this district he compared to the formations of the Parisian Basin.

Just beyond Fraga the traveller enters Cataluña; and near Lerida he meets with a gritty limestone, which at Bellock gives place to a calcareous farcilite; near Cervera this is succeeded by a limestone splitting into thin layers; all which the author thinks may be referred to the tertiary period, as the soil is full of shells belonging to the genera limnea and cyclostoma, though in his hurried examination he did not detect them in the rocks. Cervera is at the extremity of this formation, and is built on a rock of secondary limestone, which forms the fundamental rock visible between that city and Igualada. The country is now finely broken into wooded hills and cultivated valleys; but the limestone between Igualada and Esparaguerra gives place to a conglomerate, with a basis resembling ordinary sandstone which slightly effervesces with acids. This conglomerate is a considerable formation, not only occurring in the plains, but forming hills, and covering the flanks, and constituting the lofty spiry ridge of Montserrat. This rock forms thick beds, which in the defile of Martorel are seen, in the channel of the Lobregat, to rest directly on a glossy

clay slate, the laminæ of which are slightly contorted. In one place the slate was traversed by a wide vein of greenstone porphyry, in which the crystals of felspar were large. The abrupt southern termination of Montserrat, in this defile, shows the slate immediately covered by a reddish sandstone, containing rounded nodules of quartz, and sometimes fragments of the clay slate. The upper portions assume more and more the appearance of the conglomerate already described. The enormous mass of Montserrat is composed of these rocks, which probably belong to the greywacke formation. In proceeding to Barcelona, the sandstone continues to be visible as far as St. Andreu and Papiol, where it forms low cliffs; but in the fine plain of Barcelona, the rocks are covered by a rich clay marl, only broken near the sea by a sandstone, containing turritellæ and turbines, and forming the hill of Monjuic, which is crowned by the strong fortress of that name.

In the author's excursion to Cardona, he passed the northern ridge of Montserrat; which, instead of forming, as usually represented, an isolated mountain, should rather be considered as the termination of a chain, the general direction of which is from N.N.E. to S.S.W. The shattered spires of the Caval de Bermat are formed of the same farcilite, which extends as far as the dangerous defile at *Eremita de San Jayme*. Here it is succeeded by strata of sandstone flag, which the author traced beyond the city of Manresa, to the eastern side of the Rio Cardonero; but the western bank of that river exhibited strata of a dull grey limestone. As the traveller approaches Cardona, these rocks are concealed by a vast bed of reddish, marly clay; and, in ascending to the city of Cardona from the Cardonero, he is surprised to find, instead of rocks projecting from the soil, grey masses of salt of great purity.

Referring to his more detailed description of the salt-mine of Cardona in the Geological Transactions, the author illustrated his short account by a drawing of this celebrated mine. The salt presents a nearly mural precipice of about 400 feet high, of a greyish white colour, having its surface channeled by the rains into numberless smooth hollows with sharp edges. The body of the salt is so pure, that to convert it into the whitest culinary salt, it is merely ground in mills. This remarkable deposit has been described as a mountain *of salt*; but this the author considers as incorrect; it rather seems to be a valley filled up with that mineral. The nearest visible rocks, on both hands, incline towards the salt valley; the hills on both sides of it are higher than the bed of salt; and the whole is covered by a stratum of plastic clay, which defends the salt from wasting by the elements. This mine is a royal appanage, rigidly guarded by sentinels stationed on the adjacent heights, who have orders to fire on all who enter the mine without authority; a circumstance which renders caution necessary in those who examine it. There were only one hundred miners employed in 1814, the period of the author's visit to Cardona, who were under the direction of ten subordinate officers, and a general superintendent. The miners earned two pecetas (about two shillings) a day; they work from six A.M. to seven P.M., with the

intervals of from eight to nine for breakfast, and from twelve to two for dinner and the *siesta*. The salt is sold for seven and a half pecetas for 5 arrobas, or about 130lbs. avoirdupois. The only mode of conveyance from the mine is on the backs of mules or asses, over rugged mountain passes and dangerous defiles; yet a canal might easily be constructed to bring this valuable product down by the Cardonero and the Lobregat to the sea, and thus all Spain might be for ages supplied from this immense deposit of the purest salt, at a moderate price.

The surface of the salt in that fine climate appears perfectly dry; and it is little liable to deliquesce, owing to its remarkable purity, and especially the absence of earthy muriates.

In proceeding from Barcelona northwards, the author found the fertile marly soil to rest on sandstone, until he reached Caldetas, on the sea coast, where a crumbling granite is exposed, in a spur proceeding from the mountains on the left. The neighbourhood of this place has thermal springs, which seem to arise in the granite; but the greatest peculiarity he observed was the occurrence of numerous veins of hornblende and porphyritic greenstone traversing the granite, which are lost soon after passing Areñs. The road thence leaves the coast, and winds among the mountains, in which strata of variegated marble abound, especially near Pineda; but the only rock visible on the route was disintegrated granite, which however disappears as we descend into the valley of Gerona, which is filled with marl; but that city stands on a hill of crinoidal limestone. From Gerona to Figueras the marl rests on this limestone. At Bascara a calcareous farcilite is found; but the mountains on the left appear to consist of primitive rocks, as indicated by the fragments rolled down by the streams. Between Figueras and Junquera the soil is a deep loam, containing numerous rounded nodules of limestone; but after passing *Pont des Moulins*, large blocks of grey granite make their appearance; and in one place the author observed limestone strata in direct contact with the granite. The rocks round Junquera are granitic, consisting either of a small grained grey granite, or a reddish brown syenite. This granite continues up the pass of Junquera, almost to the confines of France, where a shining unctuous mica slate conceals the granite, and is the only visible rock as far as the French fortress of Bellegrade. A little beyond this last point, the mica slate is concealed by strata of clay slate rapidly dipping to N.E. The eastern Pyrenees are more steep on the French than on the Spanish side. The chain is not there very lofty; but from Bellegrade a most magnificent conical peak appears far to the West towering to the clouds.

On some Intersections of Veins in the Mines of Dolcoath and Huel Prudence, in Cornwall, and on their bearing on the Theory of the Mechanical Origin of their ("heaves") Dislocations. By* W. J. Henwood, *F.G.S., Secretary and Curator of the Royal Geological Society of Cornwall, H. M. Assay Master of Tin in the Duchy of Cornwall.*

The object of this paper was to show, that the theory of mechanical disturbance, by which it was contended that mineral veins were heaved or dislocated in consequence of the upheaving or movement of the strata, or of the forcible intrusion of igneous rocks, in a state of fusion, intersecting and shifting pre-existing veins,—would not explain the phænomena as displayed in the mines of Cornwall, and is opposed to the experience of practical miners. To support this objection, Mr. Henwood adduced two examples, one from the Dolcoath Mine in the parish of Camborne, in which three *lodes*, the first being E. and W., and dipping 65° North; the second bearing 30° N. of W., and dipping 80° North; the third bearing 15° N. of W., and dipping 70° North; and, further, an Elvan course, bearing 20° S. of W., and dipping 34° N., are all traversed by a *cross course* bearing N. and S., and dipping 87° W., the result of the intersection being a very unequal heaving of the *lodes*. The first of these (or Entral *lode*) has shifted the *cross course* 9 feet to the left, and is itself undisturbed. The second *lode* is heaved by the cross course 12 feet to the right. The third *lode* is heaved 30 feet to the right; and although the west portion of that *lode* is actually in the Elvan course, that course is neither heaved by the *cross course*, nor by either of the *lodes*. In the second case, or that of Huel Prudence, parish of St. Agnes, an Elvan course bearing E. and W., and dipping 45° N., a *lode* bearing 5°S. of W., and dipping 70° S., and another *lode* bearing 10° S. of W., and dipping 68° N., are intersected by a *cross course* bearing 12° W. of S., and dipping 80° E., the result being, that the Elvan course is heaved 42 feet to the right, the first *lode* is heaved 30 feet to the right, the second *lode* is heaved 9 feet to the right. Mr. Henwood asks, how can such varied effects be attributed to any one simple vertical movement or disturbance? and, more particularly, how can the heaving of two *lodes* both to the right, although they dip in opposite directions, be thus accounted for; since, on such a theory, it would appear that one ought to have been heaved to the right, and the other to the left?

Mr. Henwood, having thus stated his objections to the received theory of mechanical disturbance, further observed, that he believed no one doubted that the tin veins at Carclaize, and the copper veins at Huel Music, were the result of segregation, and contemporaneous with the contiguous rocks; but as these little *lodes* exhibited, on a small scale, all the characters displayed by the large *lodes* on a great scale, he did not see that any unexceptionable distinction could be drawn between them.

* When a *lode* is not continuous on opposite sides of a *cross course*, it is (in Cornwall) said to be *heaved*.

On the Unity of the Coal Deposits of England and Wales.
By Dr. W. H. CROOK.

The object of this communication was to show, that the coal fields of England and Wales were not distinct basins, but that the supposed basins were merely detached portions, which had been elevated by the agency of syenitic and trap rocks, of a much larger deposit, that was spread over the greater part of the districts now covered by the new red sandstone rocks. Dr. C. conceived that this view may be extended to the coal of Belgium, and that of the north of France, and the north-west of Germany; the carboniferous beds of these countries, as well as those of our own, having originated, in his opinion, in a drift of vegetable matter from countries lying to the East and E.S.E. of them: and he also stated, that the extent and richness of our coal deposits, especially in the midland counties, arose, in a considerable degree, from the impediments raised to the transit of the drifted matter by the slate and other ancient formations of Wales and Cumberland.

Mr. Young, of Nova Scotia, brought under the notice of the Section a work on the geology of that country, accompanied by a geological map by Dr. Gesner.

Notice of an Incursion of the Sea into the Collieries at Workington.
By Professor SEDGWICK.

The author commenced by pointing out, in a descending order, the succession of strata from the new red sandstone to the coal beds which are intersected by numerous cracks or breaks filled with dirt or other substances, and called faults or dikes. He then enumerated some of the more remarkable faults, one of which, an upcast fault, is to the amount of 600 feet, and a down fault to the amount of 100; in the one case the more valuable beds having been brought high up, and entirely removed by denuding causes, and in others thrown down in a corresponding manner; a sinking of 135 fathoms being required at the Isabella Pit to get at the main coal. Prof. Sedgwick next drew attention to the difference of position between the coal beds worked by Lord Lonsdale and Mr. Curwen; in Lord Lonsdale's collieries the beds dip under the sea, and therefore with the extension of the workings increase the distance between them and the water; whilst, in Mr. Curwen's, the beds cropped out under the sea: and, further, the danger arising out of this position was increased by the shattered condition of the strata,—the consequence of faults. The result of these combined evils was, that the working having been carried within 14 fathoms of the sea amongst the troubles, or faults, of the strata, the strata suddenly subsided, and the sea burst into the works. The torrent was, however, occasionally checked by accumulations of rubbish, until the pressure had forced it through them; hence its action was by fits, and each renewed rush was accompanied by a roaring wind, the air

in the passages being displaced by the water. Breeze followed breeze, as torrent succeeded to torrent, and soon the whole 20 miles of passages and railways were completely filled. Twenty-seven men were below, and, when the noise reached them, were totally unable to conjecture its cause, though danger of some kind was manifest. Four escaped under the guidance of Brennagh, an Irishman, by following the air-courses; Brennagh, himself, in the midst of all this fearful noise, perplexity, and confusion, stopping in his progress, and going back 100 yards to save an old man. These men passed over a distance of 3000 yards in making their escape, and when they reached the spiral staircase, all the other routes having there become stopped, the wind roared through it with such violence, that it was heard a quarter of a mile off. At this time Bland, the last man coming up, was buoyed up by the wind, and, just as he expected deliverance, a trap-door, caught by the current of air, closed upon him. He, however, was not dismayed, but at once punched a hole, when the valve opened, and he was actually blown out of the pit mouth*.

On the Mud deposited by the Tidal Waters of the Severn, Usk, and Avon, and other phænomena connected with the Waters of these Rivers. By John Ham, *of Bristol.*

The author, having described the peculiarities attending the violent influx of the tide along the gradually contracting estuary of the Severn, till it finally produces the bore in that river, and rises to an extraordinary height in the Wye—observes, "This incessant agitation and conflict of waters naturally render them very turbid: that they do not readily mix when the fresh water is sent back by a high wave, or what may be called a *wall* of sea water, may be conceived; but where the Channel is wider, and its bottom full of inequalities, it might be supposed that the mixture was more readily accomplished; and so it is, for the regularity in its specific gravity at the same season of the year is great, as I have found it the same in the month of August in the present year, and in 1822, viz. 1020. This indicates that it is rather less than the specific gravity of the open sea or ocean, remote from rivers, which is found to vary from 1020 to 1028.

"The bed of the Bristol Channel, on the Welsh coast, is much more shallow than on the opposite coast; therefore, a much greater space of the bottom is exposed to the rays of the sun on that side at low water. This will partly account for the superior temperature of the water on the Welsh coast, which I found to be 67° Fahrenheit in the month of August, and 65° only on the south-east side of the Channel, near the mouth of the river Avon.

"To the shallowness of the water on the Welsh side must also be

* Professor Sedgwick, having made some reflections on the lesson of caution afforded by this melancholy catastrophe, appealed to the Section in behalf of the gallant Brennagh, when 34*l.* were immediately subscribed.

attributed the increased quantity of mud that it holds in suspension. Of five samples taken from the surface, the following are the results:

	per Imperial Gal.
At the mouth of the Avon the water contains	26·3 grs.
In the deep part of the Channel	28·5
Advancing farther, where the water begins to shallow	35·0
On the opposite coast	72·0
Mouth of the Usk	39·5
5		201·3
Average . .	40·3

"If that part of the area of the Channel to which these data apply be taken at 225 square miles, and the above as an average at the depth of one fathom, the quantity of mud in suspension will be about 700,000 tons. The mud in suspension gradually increases from the surface downwards."

Dr. Jeffreys of Liverpool exhibited to the Section two boxes of teeth and bones from the Caves of Cefn, in Denbighshire.

On the Geology of the Coal District of South Lancashire. By JAMES HEYWOOD, *F.G.S., Senior Optime of Trinity College, Cambridge.*

The great coal district of Lancashire occupies an area of more than 400 square miles, of which the largest and the most important portion, including an area of at least 250 square miles, is contained in the southern division of the county.

Extensive beds of gravel, sand, marl, and moss, generally conceal the rugged outline of the Lancashire coal measures from the eye of the geologist; but the industry excited by commercial enterprise has found a way to obtain access to the mineral treasures of the district through the deepest superincumbent strata, and the rich produce of the coal mines has aided, at the same time, in the centralization of manufacturing and commercial power in Lancashire.

The eastern boundary of the great Lancashire coal district is formed by the lofty range of gritstone hills which separates the county of Lancaster from the West Riding of Yorkshire.

This gritstone range of hills is continued from the heights of Pendle Hill, Padiham, and Boulsworth, in North Lancashire, by Cliviger, Todmorden, Blackstone Edge, Stanedge, and Longdendale, to the north of Derbyshire. From the steep acclivities above Todmorden, a transverse ridge of gritstone hills breaks into the central portion of the Lancashire coal district, and elevates, in detached masses, many isolated

fields of coal. Some of these isolated coal fields are found on the summits, others in the valleys, of the subjacent gritstone series, and at the western extremity of the transverse ridge of gritstone, the gritstone hills are surrounded with beds of coal.

At the northern extremity of the Lancashire coal district, the carboniferous strata are found in the form of a large natural basin, whose outer edges rest upon the gritstone rocks of Boulsworth Hill, Pendle Hill, and Padiham Heights. In the centre of this basin, at the Foxclough Colliery, near Colne, the inclination of the coal beds is very gentle, being only 1 foot in 12, and rising on all sides.

Three miles to the south-west of Colne, at the Marsden Colliery, the level of the coal mines crosses the valley of the river Calder, and the carboniferous strata rise on each side of the valley towards the gritstone hills, which form its boundaries.

Very steeply inclined coal mines, called "rearing mines," have been noticed on the northern boundary of the Lancashire coal district, overlying the gritstone strata to the north-east of Blackburn. Immediately north of Blackburn, at Shire Brow, the fine quartzose sandstone, of which that hill is composed, dips to the S.S.E. at an angle of about 50°, and the shales and sandstones of the coal measures appear at the base of an adjoining hill, dipping in the same direction, at an angle of 33°.

Three miles south-west of Blackburn, red sandstone rock is visible at Feniscowles Bridge: it occurs there, in thinly stratified beds, with mica; and at Withnell, south of Feniscowles, the shales and sandstones of the coal formation make their appearance nearly in a horizontal position, or slightly inclined to the west.

Associated with the red sandstone strata, many beds of marl are found overlying the coal measures on the west and south of the Lancashire coal field, and concealing the boundary of the carboniferous district, so that the western and southern limits are still very imperfectly known, except by the operation of mining.

From the termination of the gritstone strata, near Blackburn, the line of coal mines on the western side of the coal district may be traced by Mawdesley and Newburgh to Blague Gate, Stanley Gate, and Bickerstaffe. South of Bickerstaffe, coal is found under Rainford Moss; in the same neighbourhood, coals were formerly worked south of Knowsley Park, and west of Prescot; and coal shales have been found under the sandstone strata at the Hazles, near Prescot.

The south-western extremity of the Lancashire coal district is situated in the neighbourhood of Tarbock. At Whiston, north-east of Tarbock, the carboniferous strata are visible on the line of the Liverpool and Manchester Railway. North of Whiston, and beyond Prescot, the beds of coal are cut off by the intervention of a large mass of red sandstone rock, nearly a mile in width; coals are worked again to the north of this sandstone rock at Gillar's Green; and the coal measures appear to be again interrupted, on the north-east of Prescot, by another portion of the red sandstone formation, which extends, in a northerly direction, beyond Eccleston.

Coals are worked very near to the red sandstone of Eccleston, and from the Thattow Heath Colliery, in that neighbourhood, a line of coal mines may be traced passing by Sutton, Parr's Moss, Ashton in Makerfield, Edge Green, Leigh, Bedford, and Worsley, to Pendleton, near Manchester. For seven miles to the north-west of Pendleton, a remarkable promontory of red sandstone stretches out as far as Ringley Bridge, on the river Irwell, and gives the very appropriate name of the "Red-rock Fault" to an enormous displacement of the coal measures, by means of which the beds of coal are abruptly cut off, and their level is changed to an average extent of 1000 yards.

Below Ringley Bridge, the precise boundary of the red sandstone rock, on the eastern side of the Red-rock Fault, has not hitherto been accurately determined. Red sandstone strata may, however, be traced on both sides of the River Irwell, from Ringley to Agecroft Bridge; and below Agecroft Bridge, the red sandstone rock is found in considerable masses in the neighbourhood of Kersall Moor, Castle Irwell, and at the dye-works near Salford Bridge. Red sandstone rock forms the foundation of the Collegiate Church of Manchester, and of numerous other buildings which rise on the opposite banks of the Irwell, both in Manchester and Salford. Beyond Manchester, the red sandstone formation may be easily seen along the course of the rivers Mersey and Irwell, as far as Warrington, Stockport, and Liverpool.

On the north-eastern side of Manchester, coal is found at Collyhurst and Bradford; the coal measures are afterwards interrupted by the intervention of the sandstone rock on the eastern side of the Bradford coal field: coals are again found above Bank Bridge on the river Medlock, in the same neighbourhood.

Beyond Denton, to the south-east of Manchester, the levels of the coal mines are carried on, in a southerly direction, towards Poynton and Macclesfield. Very minute investigation is required to determine with accuracy the line of faults, which probably forms the southern boundary of the Lancashire coal district.

Limestone is occasionally found near to the southern limits of the Lancashire coal district. At Ardwick, adjoining Manchester, the carboniferous shales are interstratified with beds of limestone, and the south-western inclination of the calcareous strata at Ardwick corresponds with the inclination of the carboniferous beds associated with them.

Nine miles to the west of Manchester, at Bedford, near Leigh, several strata of magnesian limestone are found dipping to the south-east, and very nearly conformable in their inclination with the red sandstone strata in that neighbourhood. The relative position of these rocks, as well as their relation to the carboniferous strata in the same neighbourhood, was carefully examined by the late Dr. Phillips of Manchester; and the result of his observations demonstrates, that the red sandstone strata of Bedford are inclined at an angle of 10° or 20° towards the south-east, corresponding very nearly with the inclination of the magnesian limestone; while the carboniferous strata dip to the south-west, and, consequently, the carboniferous strata are

unconformable both with the magnesian limestone and with the red sandstone strata at Bedford, in South Lancashire.

The beds of coal on the east, the north, and the north-west of Manchester, are inclined towards the west, the south-west, and the south, being probably elevated from a horizontal position by the force with which the gritstone hills behind them were raised to their present position.

A grand series of parallel faults traverses the eastern portion of the South Lancashire coal district in a north-westerly direction, and of these the principal fault, which has been already mentioned, as the Red-rock Fault of the valley of the Irwell, is visible between Clifton and Ringley on the bed of the river Irwell, about six miles to the north-west of Manchester. In this locality, the precise direction of the Red-rock Fault has been ascertained to be N.W. by W.; and in the line of the fault, a considerable number of rectangular prisms of sandstone belonging to the coal formation are distinctly visible, symmetrically arranged in a vertical position, or steeply inclined, as if suddenly elevated. On the western side of the fault, at Clifton, the sandstones of the coal measures dip 10° to the S.S.W., and on the eastern side the red sandstone strata are nearly horizontal, or dip slightly to the S.S.W., thus showing nearly the same inclination of the strata on each side of the Red-rock Fault of the Irwell.

The occurrence of the Red-rock Fault has occasioned a very remarkable displacement of the beds of coal in the valley of the Irwell, near Manchester. On the western side of the fault, the highest beds of coal in the carboniferous series of South Lancashire are worked, and the lower mines successively crop out between Manchester and Bolton, while the higher mines of the coal series are worked on the eastern side of the fault. If the level of the four-foot coal mine, one of the highest mines in the series, be traced from Worsley to the Red-rock Fault, it will be found that at Worsley the four-foot mine encounters a considerable fault of 400 yards, which changes its level to a more northerly position. A second fault, of 600 yards, again removes the level of the four-foot mine further north, and the level of the mine ranges towards the south-east as far as Pendleton. On the eastern side of the Red-rock Fault the level of the four-foot mine is found at Ringley, and the continuation of this level meets the Red-rock Fault near the junction of the Irwell and the Tong rivers.

At Ratcliffe Bridge another fault, parallel to the great Red-rock Fault, crosses under the course of the river Irwell, and at Blackford Bridge, on the same river, another parallel fault occurs, accompanied with red sandstone rock, which is again succeeded by the ordinary coal measures.

North of Bury, at Brandlesholme, on the river Irwell, two parallel faults have been observed ranging near to each other, and parallel in their north-westerly direction to the great Red-rock Fault of the district. Above the first fault, at Brandlesholme, the inclination of the dark ferruginous shales is 14° or 15° N.E. by E., and, below the fault, sandstone strata succeed, with an inclination of 50° south.

Beyond the dark ferruginous shales, sandstone strata occur, inclined,

similarly to the inclination of the shales, at an angle of 15° or 20° N.E. by E., and in these sandstone strata the second fault is visible. Above the second fault, the dip of the sandstone strata is from 5° to 10° east. In the line of the second fault, the sandstone strata are projected vertically upwards, and are accompanied with ferruginous septaria. The interval of about 6 feet, occasioned by the second fault, is filled up with ferruginous clay.

On the opposite side of the Irwell, the sandstone strata are raised vertically in the lines of these two faults, and are thus contrasted with the ordinary inclination of the sandstone strata, which is very gentle.

The same faults are again visible on the river Roch, between Bury and Heywood, accompanied with similar phenomena to those observed at Brandlesholme. The sandstone rocks and black shales of the coal measures are found in a vertical position in the lines of the faults, while the general inclination of the carboniferous strata on each side of the fault is very gentle near Heywood, and does not exceed 10° towards the south-east.

Many of the preceding details on the exact position of the strata in different localities have been taken from observations in several portions of South Lancashire, recently conducted by zealous and assiduous friends, at the request, and under the superintendence, of the author of this report. The author has here endeavoured to arrange and classify the materials of geological information which were afforded to him by the kind assistance of several proprietors of coal mines, and by other individuals well acquainted with the structure of the coal district.

At Pendlebury, near Manchester, there are 21 beds of coal, whose total approximate thickness amounts to 25 yards, while the approximate thickness of the strata associated with the coal amounts to 1136 yards. Hence, the proportion of the beds of coal to the strata associated with the coal, is as 1 to 45 nearly.

At Haigh, near Wigan, there are 27 beds of coal, whose total approximate thickness amounts to 26 yards, while the total approximate thickness of the strata, associated with the coal, amounts to 1036 yards, and the consequent proportion of the beds of coal to the associated strata, is as 1 to 40 nearly.

On the Coal-Measures of West Lancashire. By W. C. WILLIAMSON.

Mr. Williamson exhibited and explained several sections, combining the result of his own investigations with the practical observations of miners. A general section was exhibited, drawn up from observations at different points, of the saliferous and carboniferous strata, extending downwards nearly to the millstone grit. At Manchester the magnesian limestone almost disappears, merging with the clays of the lower new red sandstone, but contains the characteristic *axinus obscurus* and other fossils. The lower new red sandstone is unconformable to the coal-strata in

the neighbourhood, the former dipping at the rate of about 16° and the latter 23°, no gradation consequently existing. At the top of the carboniferous strata is a series of limestones, (resembling those observed by Mr. Murchison at Lebotwood near Shrewsbury), described by Mr. Williamson in the Phil. Mag. of Sept. 1836. Including the space occupied by these is an extent of 1400 feet of clays, sandstones, &c. forming the top of the series, before reaching any *workable* coal, when those of the small isolated coal field of Bradford* commence. Mr. Williamson supposes the portion of the carboniferous group represented to be at least 6000 feet thick, whilst about 400 feet more are wanting to complete the series down to the millstone grit of Phillips's Geol. of Yorkshire. The number of *workable* seams of coal averages about 21, having an aggregate thickness of about eighty feet. Towards the upper and middle portions of the series, the strata chiefly consist of shales, clays and sandstones, the latter often from thirty to seventy feet thick, and forming good building-stones, especially the 'Peel delph' rock. At the depth of about 5000 feet flagstones prevail, corresponding with the upper flag measures of Yorkshire, and with them are two coarse grits, each about eighty feet thick. These repose upon a series of flags,† and the whole with their shales are based on the millstone grit. The remains of plants seem to be irregularly distributed: *Neuropteris cordata* has only been found at the top. In some instances seams of coal appear characterized by an unusual prevalence of plants, but are liable to much variation. Mr. Williamson has found remains of fish in connection with most of the coals from the uppermost limestone to the lowest coal in the 'mountain mine.' They chiefly consist of teeth of *Diplodus gibbosus;* scales and teeth of *Megalichthys Holopticus,* two or three species; *Palæoniscus* and allied genera, three or four species; Coprolites, teeth and scales of singular forms and uncertain affinities. *Unionidæ* are generally diffused; but above the flag-series is a seam, three inches thick, entirely composed of individuals of a large species; and immediately above the mountain mine, is found *Goniatites Listeri* and *Looneyi* in large nodules, together with *Pecten papyraceus.* Mr. Williamson also exhibited several smaller sections, showing the variations of the strata at similar heights above the same coal, and the impossibility therefore of judging from mere isolated sections. The general resemblance, however, seems to show, that the various coal deposits are parts of one series, pushed up by the protrusion of the millstone grits.

On the Dislocations of the Coal Strata in Wigan and the Vicinity. By William Peace.

The district surrounding Wigan is intersected by a great number of faults or dislocations running nearly in straight lines, as shown on a map produced by the author. These faults, which run nearly parallel to the magnetic meridian, and varying only about 10 degrees from it to the westward, dislocate the strata to a much greater ex-

* Near Manchester.

† The Haslingden flags.

tent than the cross faults which run respectively S.E. and S.W.; and they also form, in many instances, the terminations of the cross faults, being rarely, if ever, crossed by them. The average 'throw' of the principal or northerly faults is about 340 yards, whilst that of the cross faults is only about 44 yards. Beginning at the easterly side of the map, which comprises about 50 square miles of the district, and proceeding to the westward, the

1st	principal fault	throws down the strata	to westward	.	171 yards
2nd	do.	do.	do.	about	500 do.
3rd	do.	throws up	do.	do.	340 do.
4th	do.	throws down	do.	do.	440 do.
5th	do.	throws up	do.	do.	540 do.

and the sixth throws the strata up to the westward about 220 yards, the average distance between them being about 1200 yards. The level and dip of the coal vary in each belt of strata respectively included between the main faults. Between the two most easterly of them the dip is nearly south, whilst between the second and third it is west, or at right angles to the former. The plan shows the variations of the dip and level in each belt of strata, the directions of which are indicated by blue lines. The lines of the subsidiary or cross faults generally form angles of from 30 to 60 degrees with the main fault, and scarcely ever form right angles. The fault, or plane of dislocation, is rarely, if ever, found to be vertical, but deviates generally from that position from 20 to 40 degrees. It is also invariably found that the inclination of the plane of dislocation indicates the direction in which the strata are displaced. If, for instance, the vein of the fault slopes, forming an inclined plane, the foot of which is nearer the observer than the summit, the strata are in that case removed upwards; if, on the contrary, the plane of dislocation slopes from the observer, the strata are removed downwards, as shown by the Section. In all the seams of coal subjacent to the district comprised in Mr. Peace's map, the direction of the cleavage of the coal strata in every seam is invariably N.W., and varies but a very few degrees; and in this important characteristic they correspond with many observations the author has made in the coal districts of Yorkshire, South Wales, and elsewhere, which induce him to believe that it is an effect of one and the same cause acting simultaneously on the whole of our coal strata during their deposition.

On that part of the South Welsh Coal Basin which lies between the Vale of Neath and Carmarthen Bay. In explanation of a geological map of the district, laid down by the author on the sheets of the Ordnance Survey. By Mr. LOGAN.

The map exhibited the outcrops of the various seams of coal in the district in question, and the dislocations they suffer from faults.

All the principal faults run in a north and south direction, and present an extraordinary degree of parallelism.

They coincide with the joints of the rocks, and it is very usual

before coming to a master fault, to meet with one, two, or more parallel smaller ones, throwing the measures up or down in the same direction.

The master faults appear in general to run across the whole basin, and to extend into the old red sandstone.

Minor faults occasionally branch from the larger ones, and perhaps in some instances two very considerable faults merge into one. But it appears when such is the case both the faults throw the measures the same way.

The dip of the measures is often different on the opposite sides of a fault; hence it happens that running along the course of the fault the down-throw or up-throw necessarily increases or diminishes.

There are instances of faults which, while they are considerable in the middle of their course, diminish to nothing at both extremes.

The author observes, "I have been informed that there are faults which, while extensive at the outcrop of the measures where the beds dip with the greatest rapidity, diminish towards the centre of the basin, the beds on the opposite sides then crossing one another and reversing their relative positions; but I am not able to point out any instance. Faults of this description might arise from horizontal movements, and there are symptoms of such movements in the limestone between Pwll Du Bay and the Mumbles Point."

The faults are seldom quite perpendicular, and it appears that in general their dip or underlie is towards the down-throw. Hence it would happen that when a block of strata lies between two up-throw faults, it would have the form of a wedge with the point downwards, and the two faults would vertically merge into one. *No working in the Welsh coal basin has yet been deep enough to get to the bottom of any of these wedges.* To this general direction of the underlie there are, however, many exceptions, particularly in the east and west faults occurring between the Turch and Tawe rivers, in the neighbourhood of the limestone irregularly thrown up in Cribbarth Mountain, and producing what are technically called leaves by the Welsh miner, a leaf being nothing more than the duplication or over-lapping of a bed, occasioned by a fault dipping at a very acute angle in respect to the horizontal plane towards the up-throw side.

The faults are of various breadths, and it would be natural to suppose that those which produce the greatest step in the measures should be the widest. But there are instances where master faults are not more than a few inches wide; and others, where faults that occasion a step of only a few feet, are said to be a hundred yards or upwards in breadth. But the author thinks the dimensions of these very wide faults are often exaggerated, as coal miners are accustomed to state the width of a fault to be the distance from good, solid, profitable ground on the one side to the same on the other, while probably the disturbed part may include several small faults.

Another circumstance connected with these faults is very important. The coal on one side of a fault is frequently very different in quality, as respects the quantity of bitumen it may contain, from that

on the opposite side; and it is remarkable that the coal on the up-throw side of the fault contains the less quantity.

In respect to the diversity that exists in the bituminous qualities of the coal from different parts of the South Welsh coal basin, it is well known that the non-bituminous, or stone coal, is found on the north side and at the west end; the bituminous coal on the south side and east end; and there is an intermediate region occupied by an intermediate quality.

Mr. Logan has lately ascertained that, in two or more of the principal collieries on the south side of the basin, near Swansea and Llansamlet, though the lower seams of coal carry their bitumen to points deeper in the earth than the higher ones, they begin to part with it at points further to the south. And it appears to him that these facts taken together, unless contradicted by further evidence, indicate the possibility of a rule in the change of quality; namely, that it occurs in parallel planes, cutting the seams of coal without regard to their strike or inclination, and dipping to the south or east of south.

There are two anticlinal lines, one running from Pont ar Dawe by Mynydd golli wartad and Llangafillach to Rhyd y mardi; the other from Loughor along the road towards Swansea, and then through the colliery of Sir John Morris at Pentre.

In the mountain limestone, on the south side of the basin, and to the east of Cefn bryn, there are two geological waves or edges running east and west.

The millstone grit appears above the mountain limestone, along the northern line of the basin; and it is also seen, but not so distinctly, on the southern side in Gower, and in the fractures of the rock which there represents it in Cel ifor Hill, near Llawhedian, and a few miles eastward wavellite is found in abundance.

On the Tidal Capacity of the Mersey Estuary—the Proportion of Silt held in solution during the Flood and Ebb circulations—the Excess of Deposit upon each Reflux, and the consequent Effect produced by the Matter thus detected in its transit, and measured at its lodgement, on the banks in Liverpool Bay; with Diagrams. By Captain DENHAM, *R.N.*

Captain Denham states the area of the Mersey, from Rock to Warrington, to be 113,171,200 square yards, and its average channel capacity 535,914,040 cubic yards, that mass of water circulating to and fro four times every 24 hours. The flood occupies $5^h\ 20'$. The velocity on the Narrows (from Seacombe to Prince's Terrace) is from 1 to $6\frac{3}{4}$ miles per hour, amounting to a transit of $23\frac{1}{4}$ on flood; the ebb is for $6^h\ 30'$, velocity $\frac{3}{4}$ to 7 miles per hour, and the amount of transit $29\frac{1}{4}$ miles. The greatest velocity on the flow is at the third hour; on the ebb, at the second: the impetus on the flow greater after the third hour than before; on the ebb, greatest on the first half ebb.

The insoluble matter held in suspension by the columns of flood and ebb amounts to 29 cubic inches for each cubic yard of water on the flood, and 33 cubic inches on the ebb,—the matter on the ebb exceeding that on the flood; so that 48,065 cubic yards of silt are detained by the banks outside the Rock Narrows each tide, except that part which the succeeding ebb disturbs.

The excess of silt thus accumulated from the 730 refluxes of a year's tides, amounts to 35,087,450 cubic yards, equivalent to a layer of mud, if equally disseminated, 21 inches thick over the first tidal area; one-third, however, of this is disturbed and carried over the second tide area; and, further, the deposit is lessened by the natural shrinking as it is consolidated (namely, into half its original bulk). The annual tangible deposit is therefore 11,695,817 cubic yards, which, equally disseminated, would produce a uniform increase of the banks, and decrease of water, in the Channel, of 7 inches. The subsidence, however, is not in equal proportions, but is directed towards certain knolls, margins of banks, and elongated spits, which protrusions cause scouring and choakings of particular channel-beds. Captain Denham further pointed out instances of the rapid filling up of certain channels, as well as the changes due to sudden change of circumstances, and the importance of preserving the present conditions of the harbour, inasmuch as regards the continuance of the present back-water in its full amount. The cross-set of the Irish Channel limits the extension outwards of the shoals; but notwithstanding this fortunate natural safety-valve, any neglect of those regulations which tend to check encroachments on the Channel, would so far facilitate the natural tendency to fill up, that in a very short period the part might be closed. Captain Denham pointed out the advantages of the new channel as compared with the old. That channel was discovered by himself, and is in itself an illustration of the resulting effects of the modification of the contour of the general tidal channel, and of the benefit to be derived from closely watching the operations, whether natural or artificial, by which it may in any way be altered.

In 1836, the new channel admitted 8208 vessels, 4077 of which could not without it have got in or out under four hours' delay upon each tide. In April 1837, 1571 vessels passed, 760 of which could not have passed any other way. The post-office packets have passed directly to and fro, with thirty-five exceptions, which exceptions, in 1832, amounted to 261, involving the necessity of transferring the mail and passengers by tender or boat. And, further, out of 29000 vessels that entered the port in the last two years, only nineteen had experienced serious difficulties.

Having thus shown the surplus quantity of mud which is at each tide deposited and added to the banks,—the natural tendency resulting from this accumulation to fill up the channel,—the fortunate existence, under the influence of the present conditions of the tidal or water-way, of a good and available channel, and the paramount necessity of securing the existence of that channel by allowing no such alteration in the boundaries of the water-way as should, by lessening

the back-water, diminish the scouring of the reflux tide, or, by altering the form of the river-shores, tend to throw the current into new directions, and to stop up the existing channels; Captain Denham strongly urged the propriety of a power, vested in local guardians, to interfere whenever attempts should be made to encroach by embankments, or in any other way, on the present high-water-marks, as, in the present state of the law, a vital injury might be done to the port before an injunction could be obtained to restrain such dangerous operations. Captain Denham then explained and exhibited the simple gauge by which he had drawn up the water from various depths, to test the quantity of earthy matter suspended in it, and thus to measure at once simply and effectually, the aggregate quantity silently and almost imperceptibly circulating with the waters of this great estuary, and to deduce, with certainty, the practical as well as geological results of a continuance of the action of such natural causes under their present circumstances, and of the probable effect of any artificial modification of them. This instrument is a cylinder, seventeen inches long, and four in diameter, having a valve at each end, the lower opening inwards, the upper outwards; so that on descending, both valves would be opened by the pressure of the water, which would flow freely through the cylinder, and, on ascending, both valves would be closed, and the water which had entered at the lowest point of its descent, retained within it. The samples of water were taken up at half-hour intervals during the whole of the flood and ebb, and at depths in each series from six feet to thirty. The waters were more turbid at two hours' flood, and at two, three, four hours' ebb, and the water at thirty feet depth contained $\frac{1}{10}$ more of silt than at other depths. Thirty feet being the height of the spring-tide column, that was the maximum depth gauged.

On the Changes which have taken place in the Levels of Scotland. By Mr. J. SMITH.

Mr. Smith stated that there was abundance of evidence that changes had taken place in the relative levels of land and sea in Great Britain, as well as elsewhere. The phænomena, however, proving this fact had been involved in confusion under the title of diluvium; but he had full reason, from a careful examination of the fossils, to decide that much of these deposits belonged to the tertiary series, and not to the more recent deposits called diluvium. He had traced them in the county of Ayr, and indeed all round Scotland, the general height being 40 feet, though Mr. Gilbertson had stated an instance in which such a deposit had been found at 300 feet; from its generality, however, he considered 40 feet to have been the height of a distinct ridge or deposit. Finely laminated clay is a principal member of this deposit, and from the proportion of extinct and recent species, in the whole 113 species of shells, which he had discovered, he considered the deposit to agree with the Newer Pleiocene of Messrs. Lyell and Deshayes.

On an Apparent Analogy between the New Red Sandstone of England and Ireland. By Captain Portlock.

Capt. Portlock pointed out that he had first brought under the notice of geologists, at the Dublin Meeting of the Association, the occurrence of fossil fishes in the new red sandstone of Tyrone. These he submitted to Professor Agassiz, who considered them a new species of the genus Palæoniscus, which he named *Palæoniscus catopterus.* As the genus Palæoniscus extends into the coal strata, Capt. Portlock wished to obtain some further evidence as to the true position of the sandstone containing these fossils. On excavating for this purpose all round the limited space in which the fishes had been found, he failed in meeting any more fishes, but he arrived on the same level in the quarry at thin red clay partings, exhibiting numerous impressions of a small bivalve shell, which both Mr. Strickland and Mr. Murchison on examination considered identical with the bivalve they had found in a portion of the new red sandstone of England, considered by them to belong to the keuper division of that great formation. This shell is the *Posidonia minuta* of Goldfuss, and is given by that author as a keuper fossil. According to Bronn, however, it is not confined to the keuper; and Capt. Portlock considers therefore the discovery of this shell in the Irish new red sandstone as valuable, inasmuch as it establishes a general analogy between it and that of England, but he does not consider it sufficient alone to decide that the sandstone containing it belongs to the keuper.

On the leading features of the Geology of Ireland, and more particularly the situation and extent of the great Carboniferous or Mountain Limestone district, which occupies nearly two-thirds of the Island. By R. Griffith, *F.G.S., &c.*

In illustration of the succession of rocks which compose this extended formation he brought forward a great section of the country, commencing on the sea coast below Benbulben, in the county of Sligo, and extending from thence nearly in an eastern direction to Butler's Bridge, in the county of Cavan, a distance of 50 miles. This section, which exhibited in a very striking manner the profile of one of the most remarkable secondary districts in Ireland, and which crossed the summits of Lacka, Lugnaquilla, Cuilceagh and Slieve Rushin Mountains, was laid down to a scale of 6 inches to a mile in length and 200 feet to an inch in height; the data for its construction, both for the heights and distances, having been taken from the Ordnance Survey.

In describing this section, Mr. Griffith stated that the grauwacke slate of the county of Cavan was succeeded to the west of Butler's Bridge by a series of strata, consisting of alternations of carboniferous limestone, yellowish grey sandstone and dark grey shale, amounting to a thickness of about 200 feet. These strata, to which Mr. Griffith gave the name of the yellow sandstone, rest unconformably on the grau-

wacke slate, and are considered to form the first or lowest member of the carboniferous limestone series of Ireland.

In other localities, particularly in the county of Donegal, north of Ballyshannon, the strata belonging to this, the lowest members were stated to be of much greater thickness, and to contain with the limestone beds alternations of coarse-grained conglomerate, having a yellow or brownish-yellow base.

At Belturbet, in the line of section, the yellow sandstone series is succeeded by the lower limestone, which consists of a succession of beds of carboniferous limestone, more or less pure, and varying in colour from light smoke grey to dark blueish grey; these strata amount to a thickness of 350 feet in the line of section.

In other localities in Ireland the lower limestone contains abundance of black and occasionally grey and reddish mottled marbles of various tints, and the whole series abounds with marine fossils similar to those which occur in the mountain limestone of Derbyshire, north of Yorkshire, Northumberland, &c.

Above the lower limestone we have a series of beds, consisting of alternations of black or dark grey shale, dark blueish grey impure limestone, and yellowish and occasionally reddish grey sandstone, altogether 400 feet in thickness.

These peculiar strata, which occur also in the limestone formation in the neighbourhood of Dublin, have received the name of *Calp* from Mr. Kirwan, and Mr. Griffith adopted that name to distinguish this particular division of the carboniferous limestone.

In the line of section, the calp series which succeeds the lower limestone to the west of Belturbet occupies the country as far as Ballyconnell, situated at the base of Slieve Rushin Mountain, where it is succeeded by the upper or splintery limestone, which in this mountain is 420 feet in thickness; while in Cuilceagh Mountain, situated to the west of Swanlinbar, it is 600 feet in thickness.

The upper or splintery limestone is distinguished from the lower by its numerous crags and mural precipices, which often present the character of rude columnar façades; it is usually cavernous, and the streams falling from higher elevations are frequently lost in fissures, and flow through subterranean channels, till at length they burst forth from the lower strata of the series, and flow down the more gentle declivities of the calp shale beneath them.

The Great River Shannon has its source in a cavern of the upper limestone, which is situated at the western base of Cuilceagh Mountain, at an elevation of 342 feet above the level of the sea.

This limestone is equally abundant in fossils with the lower, and nearly the whole of the species and varieties which occur in one have equally been discovered in the other.

The splintery limestone forms the upper member of the carboniferous limestone series, which, in the line of section exhibited, amounts to a total thickness of 1750 feet.

On the summit of Slieve Rushin, and at the Cave of Pulgulm, situated on the eastern declivity of Cuilceagh Mountain, and several other

localities in the line of section, the carboniferous limestone series is succeeded by the mill-stone grit formation. In Cuilceagh Mountain, where the series is best developed, the lowest member consists of three great beds, or successions of beds, of yellowish white quartzy sandstone, having beds of black shale interposed between each; these beds amount altogether to a thickness of 500 feet: they are succeeded by a series of beds composed of black shale, which in the lower region of the mountain alternate with dull grey earthy limestone, containing varieties of Productæ, Spiriferæ, Orthoceras, &c.

As we ascend, the limestone beds gradually disappear, and in lieu of them we find the shale to alternate with thick beds of argillaceous ironstone, and occasionally with septaria of ironstone; the shale beds contain a profusion of fossils, the most abundant of which is a variety of Posidonia, but several species of Goniatites, and a remarkably small species of Orthoceras also occur.

Still continuing to ascend, the ironstone beds become thin and at length disappear, and the upper portion, amounting to a thickness of about 250 feet, consists altogether of fine-grained black shale, containing organic remains, but particularly Posidonia, but not so abundantly as in the lower beds, which alternate either with the impure limestone or the ironstone.

This great shale, which is altogether 700 feet in thickness, is succeeded by an accumulation of beds of yellowish white sandstone, about 250 feet thick; in the lower portion, next the shale, the sandstone beds are thin, and alternate with sandstone, slate, and shale; the upper consists of thick beds of yellowish white quartzy sandstone, some of which are rather coarse grained, and assume the true character of mill-stone grit.

This rock, which forms the summit of Cuilceagh Mountain, and is elevated 2188 feet above the level of the sea*, occasionally contains vegetable organic remains, particularly some varieties of Stigmaria.

In the line of section to the west of the Valley of the Shannon, the mill-stone grit beds are succeeded by a series of beds, consisting of shale and sandstone, with bituminous coal, amounting altogether to 200 feet in thickness.

In shale beds throughout contain casts of Posidoniæ, Productæ, Orthoceras, and occasionally a very minute variety of Trilobite; and it is remarkable that the whole of the fossil organic remains which occur in the upper members of the series above the coal, are unusually minute in their dimensions, so much so as to give rise to the idea that they belong to a dwindled species which existed possibly in brackish water, which, being uncongenial to their nature, prevented their full development.

(In illustration of this paper the author exhibited his large geological map of Ireland.)

* Ordnance Survey.

Mr. Elias Hall brought forward and explained a mineral map of Derbyshire.

The principal object of Mr. Hall's remarks was to prove that there were three distinct beds of toadstone, dividing the limestone into four beds; and that, taking the regular continuity of the strata into consideration, it was improbable that the beds of toadstone could be of volcanic origin.

The direction of the lead veins Mr. Hall stated to be 25° west of the magnetic meridian, varying, however, on the south to a direction nearly at right angles to the former. He noticed the occurrence of lead actually in the toadstone—a vein passing through it—and observed that Mr. Mawe, who had contradicted this fact, had visited the wrong pit, and therefore missed seeing the phænomenon.

On the Fishes of the Ludlow Rocks, or Upper Beds of the Silurian System. By Mr. MURCHISON.

Mr. Murchison briefly explained, that the various remains of fishes which he had collected in the uppermost beds of the Silurian System, and immediately below their junction with the old red sandstone, having been referred to M. Agassiz, had been formed by him into the following genera: *Onchus, Pterygotus, Plectrodus, Sclerodus, Thelodus,* and *Sphagodus.* Of these genera (drawings of which were exhibited), the two first mentioned only have been found in the overlying old red sandstone, but the species in the Silurian rocks are distinct*. These new forms are very remarkable as being the most ancient beings of their class which geological researches have brought to light; Mr. Murchison never having discovered any trace of fishes in the underlying formations of the Silurian System. They are associated with shells, crinoïdea, and numerous small *coprolites,* all of which will be figured in Mr. Murchison's forthcoming work "The Geology of the Silurian Region." Dr. Lloyd, the Rev. T. T. Lewis, and Mr. R. W. Evans, were alluded to as having greatly aided the author in collecting these remains.

On the Refrigeration of the Earth. By W. HOPKINS, *F.G.S.*

Mr. Hopkins stated that, though it might be difficult to reconcile to the mind the idea that the earth we see and stand on was once a fluid mass of igneous matter, and is, in fact, now a great cinder, yet that the evidence in favour of such a theory had convinced some of the greatest philosophers. The fact, indeed, of the original fluidity of the earth is established by its form, since, if fluid, it must, as a body revolving on an axis, have deviated from a globular form, and such is

* The *Pterygotus* of the Ludlow Rocks is supposed by M. Agassiz to belong to the same genus of fishes as the remarkable form which occurs in the lower beds of the old red sandstone of Scotland, and is there called by the workmen "*Seraphim.*"

proved to be the case by geodetic observations and calculations; and that this fluidity has been at least partially preserved, may be inferred from the phænomena of Basaltic Dykes evidently protruded since the deposition of the strata they traverse. The inquiry, therefore, into the temperature of the earth, at various epochs, is closely connected with that into the mode of its cooling. In entering on this it must be remembered, that though natural causes are permanent, the conditions under which they act may not be so, and hence also the effects may vary. The processes, for instance, will be different, according as the cooling is effected, in a fluid or in a solid body. If in a fluid, the refrigeration will be by circulation, and there will be a period at which that circulation must stop; but whether beginning by the surface or centre, may admit of doubt; for if the temperature of the surface be the least, the pressure is there also the least; and if the temperature of the centre be the greatest, the pressure is there also the greatest; and hence, as the expansive force of heat, and the pressure of gravitation are two opposing forces, the one resisting, and the other promoting solidification, that solidification will commence at the surface or at the centre, according as the one or the other shall preponderate; but at present evidence is insufficient to decide for one or the other; whilst the process of refrigeration was effected by circulation, the upper, or heavier (being cooled) particles would descend, and the lower, or hotter, ascend; but at the instant when the process of circulation ceased, the further cooling would be effected by conduction. According, therefore, to the different processes assumed as having operated the change of temperature of the earth, the earth may be viewed as,

1st. Entirely solid, and cooling by conduction.

2nd. As having solidified first at the centre, the pressure there overcoming the expansive force; and next, at the surface, the depression of temperature there more than compensating for the low pressure, and thus placing a fluid annulus between a solid nucleus and a solid crust; and,

3rd. As having solidified first at the surface; a solid crust surrounding a fluid centre. But as the laws by which consolidation and refrigeration are regulated are as yet very imperfectly understood, the question is still one of doubt.

Mr. Hopkins further remarked, that the increase of temperature on descending into the earth was apparently established as a fact; the question was, whether that increase was due to central heat, and the evidence is yet insufficient to solve it. M. Poisson, indeed, considers that it is almost impossible that heat should so increase to the centre, for at the temperature, which would be the result, the expansive force would be so great that no crust could resist it: and he has, therefore, advanced the hypothesis, that such temperature is not due to central heat, but that the whole solar system is now passing from a hotter to a colder portion of space, and is consequently losing the heat it had acquired in its passage; an hypothesis which has, however, met with powerful opponents.

On the Phænomena exhibited by the Plastic Clay Formation in the vicinity of Poole, Dorsetshire. By the Rev. W. D. Clarke.

Mr. Clarke stated that it was his object to show that the plastic clay had partaken of the movements and dislocations which had ruptured the chalk and subjacent strata; and further, that the denudations which the plastic clay had experienced were also dependent on the process by which the bearings and fracture of the beds had been affected; or, in other words, that aqueous denudations had here been the result of subterraneous movements, and not of any independent rush of water, such as a diluvial current. The plastic clay series, near Poole, consists of beds of sand and clay, the pipe clay containing much alum, iron, and manganese; and having, at an ancient date, been extensively worked. Many of the sands rival in intensity of colour those of Alum Bay, and some, as at the red rock of Studland, are highly inclined. Between Purbeck and the Wiltshire Avon the whole country consists of hills of sand and clay, interspersed with valleys and deep furrows, there being apparently not a particle of calcareous matter. The district is completely barren, and curiously wild; vegetable remains are extremely abundant, chiefly in the marls or clays, sometimes in a hard siliceous sand, which has been cemented into a sandstone by ferruginous matter. Some of the beds of sand have been so firmly cemented as to afford very good building stones, and Mr. Clarke thinks that the greyweathers of Wiltshire, of which Stonehenge is composed, were portions of beds belonging to the plastic clay. Mr. Clarke remarked that specimens of sand from a depth of 148 feet (or 138 feet below the harbour level) contained flint, quartz, slate, and wood; and that it was consequently a drift sand, brought, as he believed, by currents from the West. The probable thickness of the plastic clay is 600 feet, and there can be little doubt that it originally filled up the basin in which it now lies, having occupied the bed of some lake or gulph, —the sea, the boundary of the ancient beach, being apparently margined by a bed of pebbles. Since its deposition the plastic clay has been scooped out by the action of water, so that the whole country is cut up into a great number of hills and hollows. The harbour of Poole occupies one of these valleys, the sea having occupied a great depression in the line of the Purbeck range, which appears to have been the result of two faults, the space between them having dipped outwards. Many deep, dry furrows are met with along the edge of this descent. The furrows on the surface are neither ascribed by Mr. Clarke to diluvial action nor to the action of springs; but are considered as primarily cracks, or fissures, the consequence of elevatory disturbances, or of faults. From a comparison of the phenomena exhibited by the cracks, faults, and joints of the chalk and plastic clay beds, Mr. Clarke comes to the conclusion, that the plastic clay was elevated with the chalk, either at once, or by successive impulses of the subterranean forces; and consequently that the strata below the chalk have in the south of England been elevated since the tertiary period.

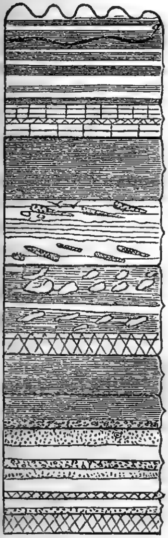
The gravel which caps the hills and islands consists principally of

chert, and appears to have a western origin; but there are also in it fragments of tertiary pudding stone, and water-worn masses of grey weathers belonging to the plastic clay, the result of local degradation. This gravel has itself been subjected to erosion, the hollows having been filled up with transported matter of similar, though altered character. So that there is evidence here of two periods of drifts, and perhaps three currents, which were probably connected with three impulses of elevation. Mr. Clarke mentioned several facts relating to Poole harbour. The land is there gaining on the sea, the town now occupying ground where fifty years ago there was deep water; and in a well bored a year ago, about a furlong from the sea, in one of the streets, Mr. Clarke found at six feet below the surface, sea-weed, and a stake and post, evidently part of an old embankment. The Bar also, which lies off the entrance to the harbour, has advanced between 1785 and 1829, (that is in forty-four years,) half a nautical mile, or about forty-six yards per annum; and as it still continues to advance, and is now not a nautical mile from the cliffs of Old Harry, it is probable that unless a new channel can be made the harbour may in process of time be closed. The Dunes or Sand hills are on the increase, a new series having grown up in five years on the south side of the entrance, which rivals those of the north; and it is remarkable that the valleys in these dunes correspond with the prevailing winds; which points to the probability that the same cause may have operated in the ancient strata before their consolidation. That elevations and depressions have taken place within recent times on the shores of Poole Harbour, may be proved by the occurrence of beds of peat at the very edge of, and in the water itself. The whole valley of the Bourne, for three miles from the sea, contains beds of peat from ten to twenty feet thick, with huge trees of oak, beech, hazel, &c., none of which now grow in the valley; and a Roman Via now terminates at about half a mile from the northern head of Hole's Bay in what is now a marsh and extensive peat bog, although it can scarcely be supposed that this road could have had originally such a termination, the probability being that it led, at its formation, to a landing-place.

On some Fossil Wood and Plants recently discovered by the Author of this Memoir low down in the Grauwacke of Devon, being one of the results of an attempt to determine the relative age and order of the Culmfield and its Floriferous Shales and Sandstones. By the Rev. D. Williams, *F.G.S.*

The author stated that he produced the specimens of fossil wood and plants in compliance with a recommendation of the committee of of the Geological Section of the Bristol Meeting. From his examination of the strata in North Devon and the Quantock Hills, he had constructed the following

Proportionate View and Tabular Order of Superposition of the respective Members of the Grauwacke System of North Devon and Somerset.



9\. Floriferous and culmiferous sandstones and shales—*a*. Anthracite.

8\. Wavellite schistus and limestones, the former cleaving into parallelograms.

7\. Trilobite slates; abundantly fossiliferous.

6\. Wollacombe sandstones, and purple slates—containing fossil wood and plants.

5\. Morthoe quartz and roofing slates, with subordinate limestones.

4\. Hard, red, siliceous slate-rock of Trentishoe.

3\. Linton slates and limestones.

b. *b*. Arenaceous slate, and conglomerate bed of limestone pebbles.

2\. Foreland and Dunkerry sandstones, thick bedded, coarse grained, and confluent.

Doddington and Over-Stowey limestones.

2\. Foreland and Dunkerry sandstones.

1\. Cannington Park limestone.

Respecting this Section, and the distribution of the remains of plants in the several parts of it, the author enters into detail, and presents arguments in favour of his opinion, that the culmiferous series of Devon cannot be separated from the subjacent rocks of the Grauwacke series, either by mineral characters, relation of strata, or organic reliquiæ. His final conclusion, after a rapid comparison of the Devon series of rocks and fossils with those of other districts, is thus expressed:—"These several considerations, added to the strong collateral and positive testimony of the wood and plants from the Sherwell sandstones, throw such accumulated weight in the scale of the hypothesis, that the culm and fossil flora of Devon belong at least to the upper Grauwacke (below the old red sandstone and mountain limestone), that he apprehends that geologists cannot hesitate to accept them provisionally as such, till far stronger facts and evidences than they are at present possessed of shall justify admitting them as a true contemporaneous equivalent for the carboniferous limestone proper, and its upper great coal field."

On the Bituminous Coal Field of Pennsylvania. *By* HARDMAN PHILLIPS.

This coal field is situated on the western slope of the Alleghany mountains. It commences in Tioga county and thence extends in a south-westerly direction to, and even beyond, the Ohio river, embracing a space of about 200 miles in length, and 30 in breadth. The coal is usually found above the level of the waters, running through every secondary hill in two, three, or four strata, according to the height of the hill, the veins being usually 4ft. 2in., 6ft., or 9ft. thick. There is great variety in the quality of the coal, that found near the centre of the field being decidedly the best. The lowest vein in that district is of very superior quality, much resembling the Newcastle coal, but still more friable, and contains more bitumen. Its specific gravity is 1·279. An analysis of this coal made by Walter R. Johnson, Professor of Geology, Mineralogy and Chemistry in the Franklin Institute of Philadelphia, afforded $22\frac{1}{2}$ per cent. of volatile matter. Other veins are harder and heavier. The coal of this field is used in Pittsburg and Cewhe county for rolling iron, but not for smelting ores. On that subject, Professor Johnson, in a letter which Mr. H. Phillips has received from him since he has been in England, says,—

"The manufacturers along the Little Imiata are looking with much interest to the completion of their railroad, so that they may receive the coal for their various works, smelting furnaces as well as forges, some of which (the Union works for example) are now hauling charcoal 10 and 12 miles, accompanied with great expense and vexation. They are determined to try coke as soon as it can be obtained. In that part of Huntingdon county, where charcoal is becoming so scarce, there is the greatest abundance I have any where encountered of rich iron ore (the brown hydrate). In some places I saw them raising it in open quarries, blasting it with gunpowder, from beds varying from 5 to 30 feet in thickness, of nearly pure ore; and though all which I visited were not so rich as that to which I have just referred, yet I no where in this part of Huntingdon county heard any intimation of a lack of that material."

The mode of digging the coal is very simple. As the lowest stratum lies above the surface of the valley, it is only necessary to open the vein, run level drifts into the hills and take the coal out on temporary railways. The general dip is very slight, only about one inch in a yard; but at the north-eastern extremity in Tioga county, and generally near the summit of the Alleghany mountains, the measures suddenly crop out an angle of about 30° from a horizontal line. The coal is accompanied by the usual deposits of fire clay and grey limestone in nodules, the former in veins of 18 inches, and the latter 6 inches in thickness.

In addition to the papers read, Dr. Jeffreys submitted to the Section a collection of bones and teeth, including those of rats, cats, sheep,

dogs, horses or cows, bears, hyænas, rhinoceros, and also the tooth of a tiger, found in a bed of diluvium which fills a cave of the carboniferous limestone at the Cefre Rocks in Denbighshire, in the estate of Mr. Lloyd of Cefre, about three miles from St. Asaph.

Mr. Gilbertson placed on the table many very interesting, and probably new fossils from the mountain limestone, and Mr. Dawson a collection of fossils from New South Wales.

ZOOLOGY AND BOTANY.

Mr. Gould exhibited drawings of new Birds from Australia and other parts of the world. He proceeded to make some remarks on the family *Trogonidæ*. This family, he stated, might be regarded as strictly tropical, and by far the greater number of species inhabited South America; none of those inhabiting Asia and Africa having any specific relation to those of America. It is a remarkably isolated group, no *direct* affinity with other forms having been discovered. In organization and economy they are perhaps nearest the *Caprimulgidæ*. They inhabit the most retired and gloomy forests, remaining secluded during the day, and appearing at night; evening and morning being the only time in which they take their prey. They usually feed on insects, capturing them during flight, but sometimes they feed on berries. They incubate in the holes of trees, and, like the majority of Fissirostral birds, produce white eggs. The tribe present among themselves but little difference of structure. There are, however, well-marked divisions according to their geographical range. Mr. Swainson divides them into five minor groups, *Trogon, Harpactes, Apaloderma, Temnurus,* and *Calurus*. The species of bird that Mr. Gould presented before the Section belonged to the latter group, and he proposed to call it *Calurus Peruvianus*. This sub-genus comprises the most beautiful birds of the whole family, and perhaps in the creation; it contains five species, only one of which until lately had been characterized. The present species, although it has not the lengthened upper tail-feathers of the *C. resplendens*, (which was exhibited), yet its relations to that species were sufficiently obvious. For this species he had been indebted to the researches of the indefatigable and scientific French traveller, M. D'Orbigny, who had recently returned from Peru.

On Filaria. By the Rev. W. Hope.

In this communication more than forty genera of insects were mentioned in which these parasitic worms had been found, and tables were exhibited containing the names of all the authenticated species, and authorities given for all the recorded instances, as well as could be ascertained.

On the Metamorphism of a Species of Crustacean, allied to Palæmon. By Captain DUCANE, *R.N.*

The remarks and observations of Captain Ducane tended to confirm Mr. V. Thompson's discovery, published some years since, of the existence of metamorphosis in this class of animals. (Captain Ducane was requested by the Committee to continue and extend his observations.)

On the Sclerotic Bones forming the Orbit of the Eye in different Birds and Reptiles. By T. ALLIS.

This paper, which requires illustrations by drawings, will be printed entire in the Transactions of the Yorkshire Philosophical Society, in whose Museum Mr. Allis's collection is preserved.

Notice of Argas Persicus, a species of Bug, found in Mianneh, in Persia, and reported to be poisonous. By Dr. TRAILL.

On the Production of Cataract by a Worm. By Professor OWEN. *Communicated by the Rev.* F. W. HOPE.

On Limax Variegatus in the Human Intestines. By Dr. DAVID WILLIAMS.

The author gave a statement of a young woman who had voided a large slug, after having suffered great pain. The slug, which was exhibited, appeared to be *Limax variegatus*. It was dead when voided, but quite unaltered.

Dr. Billingham gave a corrected description of *Trichocephalus dispar*, noticed the discrepancy of opinion between English and continental observers as to the frequency of its occurrence in the intestines of man, and recorded the result of his own examination of twenty-eight individuals who died during the last twelve months, in St. Vincent's Hospital, Dublin; eleven of whom were males, and seventeen females, of various ages, from 8 years to 70. The worms were found in the large intestines of twenty-five of these subjects, in a greater or less number, from 2 or 3 to 119. The three individuals whose intestines contained no worms were females, and had been taking certain metallic medicines, which may be supposed to be capable of destroying intestinal worms. Nothing felt by the individuals during life indicated the presence of worms in the intestines.

A Simple Method of destroying Insects which attack Books and MSS. By Sir THOMAS PHILLIPS, *Bart. Communicated by the Rev.* F. W. HOPE.

"My library being much infested with insects, particularly *Anobia*, I have for some time turned my attention to the modes of destroying them, in the course of which I observed that the larva of these beetles does not seek the paper for food, nor the leather, but the paste. To prevent their attacks, therefore, in future bound books, the paste used should be mixed up with a solution of corrosive sublimate, or, indeed, with any other poisonous ingredient. But to catch the perfect insects themselves I adopt the following plan: *Anobium striatum* commonly deposits its ova in beech wood, and is more partial, apparently, to that than any other wood. I have beech planks cut, and smear them over, in summer, with pure fresh paste (*i.e.* not containing anything poisonous); I then place them in different parts of the library, where they are not likely to be disturbed; the beetles flying about the room in summer time readily discover these pieces of wood, and soon deposit their eggs in them. In winter (chiefly) the larva is produced, and about January, February, and March, I discover what pieces of wood contain any larvæ, by the saw-dust lying under the planks, or where it is thrown up in hillocks on the top of them. All the wood which is attacked is then burnt for fire-wood; by this simple method I have nearly extirpated *Anobia* from my library. I am of opinion that a single specimen in a book of an impregnated female will soon destroy any volume should it remain undisturbed. There are also two other kinds of beetle in my library; one is a small brown beetle, and is probably a *Tomicus*, or some closely allied species. The second species was imported from Darmstadt, or Frankfort on the Maine. It is six times larger than the former, of a black colour, with white spots or stripes, and belongs to one of the modern genera of *Curculionidæ*. It appears to be partial to books bound in oak boards; it is not abundant, but very destructive."

Mr. Sandbach exhibited specimens of a new *Prionites* from Mexico, which he proposed to call *P. superciliosus*, from its having a broad blue band above the eye. He also exhibited a new species of Titmouse, supposed to be from Mexico, and which he proposed naming *Parus melanotus*.

Mr. J. E. Gray exhibited and described some rare and interesting Mammalia, which he had noticed in the Museum of the Royal Institution of Liverpool. They consisted of a young specimen of *Thylacinus cynocephalus*, old and young individuals of the *Antilope Philantomba* of Smith, specimens of *Phoca Leonina*, 12 feet long, of *Felis gracilis*, and of *Felis Javensis*. To these were added a specimen from Demerara allied to the Otter, which Mr. Gray considered as forming an entirely

new genus, of a very remarkable form, serving to connect the already established genera of *Lutra* and *Anhydra*, which he called *Pteronura Sambachii.*

Mr. J. E. Gray exhibited some new land shells observed by him in the Collection of the Royal Institution of Liverpool. One was stated to be a new genus, intermediate between *Helix* and *Anostoma*. The others were new species, which he proposed to designate by the names of *Achatina turrita, Carocolla filomarginata* (from India), and *Paludina Yatesii*, this last being the largest and one of the most beautiful of the genus. Mr. Gray also exhibited a specimen of *Unio Roisii*, Mitch., which had been recently discovered by Mr. Wm. Gilbertson, near Boughton, in Craven.

Specimens of wood, from the New Pier of Southampton, penetrated by *Limnoria terebrans*, were exhibited by Mr. W. S. MacLeay, F.R.S. The pier was constructed only four years ago, and was reported to be already in a state of decay.

A specimen of *Goliathus giganteus*, and the jaws of a large shark, (3 feet in length), caught by Captain Nash, were exhibited by Mr. F. Taylor.

Some rare Coleopterous insects, from the collection of Mr. Melli, of Liverpool, were described by the Rev. F. W. Hope and Mr. MacLeay.

Notice of Undescribed Shells. By James Smith, *of Jordanhill, F.R.S.*

Mr. Smith produced two new shells which he had dredged in Rothsay Bay, and had been named *Fusus Boothi* and *Fusus umbilicatus*. He also produced 14 species of shells found amongst recent shells at a higher level than the present high water, and which are not known as existing in a recent state.

On Victoria Regina. By J. E. Gray.

Mr. J. E. Gray exhibited the drawing of *Victoria Regina*, Schomb., sent by Mr. Robert Schomburgk from Demerara to the Botanical Society of London, and read his account of the discovery and the description of this interesting plant.

The same plant was also noticed in a communication by Dr. Lindley.

On he Structure and Affinities of Orobanchaceæ. By Dr. Lindley.

Professor Lindley made some remarks "On the structure and affinities of *Orobanchaceæ*." He stated that this order had been usually placed near *Scrophulariaceæ*, and in his "Natural System" he had included it in the Scrophulal alliance. In their didynamous stamens, superior ovary, and monopetalous flowers, they resembled *Scrophulariaceæ*. Schultz had placed this order near *Gentianaceæ*, on account of their fruit and placentation resembling those of this order. Other botanists had placed *Orobanchaceæ* near *Monotropaceæ*, on account of their membranaceous foliage and parasitical habits. There was one important point, in which they differed from *Scrophulariaceæ*, which was the position of their carpels, with respect to the axis of inflorescence. In *Orobanchaceæ*, the carpels were right and left, or perpendicular to the axis, whilst in *Scrophulariaceæ* they were fore and aft, or parallel to the axis. This pointed out another affinity with *Gentianaceæ*, which had its carpels in the same position. With regard to its affinity to *Monotropa*, there was a point which had been much overlooked by botanists, the presence and absence, or large and small quantities, of albumen in the seed of plants; he had found this a very constant character, and one of the best for indicating the affinities of plants. Both *Monotropaceæ* and *Orobanchaceæ* were distinguished for a minute embryo, lying in a large quantity of albumen. *Monotropaceæ* was a polypetalous order, but its structure generally compelled botanists to place it amongst monopetalous plants, near *Pyrolaceæ* and *Ericaceæ*. He remarked by the way, that the division of plants, according to the presence or absence, cohesion or non-cohesion, of the petals, was very artificial, and hoped that it would soon be abandoned. He thought that the affinities of *Orobanchaceæ* were stronger with *Monotropaceæ*, *Pyrolaceæ*, and *Gentianaceæ*, than with any other orders. The Professor then made some remarks "On the Placentation of Orobanche," which he said had made him doubt the correctness of the present theory of the situation of the placenta. It was generally supposed that the seat of the placenta in the carpellary leaf was its margin, so that it would be necessarily placed alternating with the dorsal suture of the carpel. Exceptions, however, frequently occur, as in *Parnasia*, *Papaver*, &c.; and the placenta is spread over the whole surface of the carpellary leaf, or on various parts of it. In the carpels of Orobanche there are evidently two placentæ, but having no commucation with the margin of the carpellary leaf. He therefore inferred, that any part of the surface of the carpellary leaf might become ovalized. He was borne out in this opinion by the fact, that leaves which occasionally produce buds, produce them from all parts of their surface, as seen in *Ornithogalum*, &c.; the production of buds on leaves and ovules in carpels being analogous processes.

On the Internal Structure of the Palm Tribe. By G. Gardner. *Communicated by* E. Bowman, *F.L.S.*

Mr. Gardner had examined the species called Coquiero by the Brazilians. He said that the fibre of woody matter descended from the leaves at an angle of 18 degrees, towards the centre, and then outwards in a more oblique angle towards the bark, near which it ramifies and descends parallel to the bark. In this plant the chord of the arc formed by their fibres is $2\frac{1}{2}$ feet.

The author thinks that Mohl's views on the structure of the palm tribe are correct.

On the Power possessed by Aged Trees to reproduce themselves from the Trunk. By R. Mallet.

The author exhibited a number of drawings of aged trees to illustrate his paper, and mentioned that the natural inarching of trees was caused by the decay of the central part of the trunk, and the formation of new wood and bark was to enclose the detached part. He said that after this had taken place, a but was formed on the inner surface, from which a stem ascended and roots descended, so as to form a new tree in the centre of the old one.

On the Milk of Galactodendron Utile. By Mr. Bickersteth.

On New and Rare Forms of British Plants and Animals. By E. Forbes.

Two new Mollusca (one allied to *Doris pinatifida,* the other to *Montagua* of Fleming), from the shores of the Isle of Man ; a specimen of *Asterias rubens,* to show its distinctness from *Asterias speciosus* of Link, and specimens of supposed new species of *Polygala* and *Euphrasia* from the Isle of Man, were presented and explained by Mr. Forbes.

On Vegetable Physiology. By Mr. Niven.

The author stated that he had made a series of experiments upon elm-trees (*Ulmus campestris*) of about 42 years old, by the removal of the bark, cambium or alburnum, and that, from the results, he was disposed to maintain that two distinct principles exist in the bark of plants, viz. one descending and forming roots, and the other ascending and forming branches. This he illustrated by showing a branch of elm ringed through the bark and cambium, and having roots descending from the upper edge of the ring, and branches ascending from the lower one.

A Notice, with the Results, of a Botanical Expedition to Guernsey and Jersey, in the months of July and August, 1837. *By* CHARLES C. BABINGTON, *M.A., F.L.S., &c.*

This paper gives a short account of the Flora of those islands, and also of the island of Herm. The author finds 725 species of flowering plants and Ferns to be natives of them, and adds to the recorded species the following 6, viz. *Hypericum linearifolium, Neottia æstivalis, Sinapis incana,* and *Mercurialis ambigua,* in Jersey, and *Arthrolobium ebracteatum* and *Atriplex rosea,* in Guernsey.

An Inquiry into the Origin of the Solid Materials found in the Ashes of Plants, their structure and office during the period of life, and the effect of their subsequent addition to the crust of the earth. By the Rev. J. B. READE, *M.A., F.R.S.*

A recent microscopic examination of the ashes of plants having led the author to the conclusion "that the earthy saline and metallic ingredients which they contain are indebted exclusively to the operation of vegetable life, both for their origin and their arrangement;" he shows the contrast of this view with that adopted by many physiologists, who rank as *accidental ingredients* in the substance of plants, all that cannot be referred to hydrogen, oxygen, carbon, or azote.

Assuming, as a basis of argument, that "the presence of organization is direct evidence of the agency of life," and that every organized portion of a plant is "a proper product of the power of vegetation," —the author proves, by a detail of experiments, that siliceous skeletons of plants, exhibiting most distinct and beautiful organization, remain in their ashes after exposure to the intense heat of a blowpipe flame; that in the white ashes of common coal may be recognized cellular tissue, spiral fibre, and annular ducts with transverse bars. The vegetable origin of coal is not only thus *proved,* but by a comparison of the ashes of coal with those of recent plants, some further insight may be gained into the nature of the plants from which beds of coal of different quality have been produced. The siliceous organizations which are respectively yielded by the Blyth, Newcastle, and Barnsley coal appear to be different.

"Silica is not the only material which forms the frame-work of plants. Lime and potash also occur as their skeletons; the ashes of the calyx and pollen of the mallow, consist of organized lime; and the ashes of the petals of the rose, as well as the pollen of the geranium, consist of organized potash." The author gives the details of his experiments, by which he endeavoured to prove the small cups which lie in the siliceous vessels of gramineæ, to be of metallic nature, and ventures to conclude, generally, that "earthy saline and metallic ingredients enter as organizable products into the structure of plants."

As much of what is above stated in regard to plants may, with suitable modifications, be applied to animals, as certain infusorial animalculæ

secrete siliceous or calcareous coverings, the author finding these products to be capable of resisting the most intense heat, speculates on the importance of the facts he has established in explaining the formation of the most characteristic rocks in the crust of the earth, and gives his reasons for believing that even in granite, as well as in flint (according to Ehrenberg), organization can be traced. A series of more than thirty microscopical illustrations accompanied the paper.

On the Chemical Composition of Vegetable Membrane and Fibre. By the Rev. J. B. Reade, *M.A., F.R.S.*

Specimens of *Erica Mackaiana* of *Babington* were exhibited by Mr. John Ball.

MEDICAL SCIENCE.

On the Influence of the Respiratory Organs on the Circulation of Blood in the Chest. By G. Calvert Holland, *M.D.*

There is little agreement, Dr. Holland observed, in the opinions of physiologists respecting the influence of respiration on the circulatory system. Some regard it as exceedingly limited, and the least efficient of the causes co-operating in the return of venous blood; others contend that it is not only the principal but sole agent in the production of this effect. The author, from experiments on himself, stated that this influence is not great in the ordinary or unexcited conditions of the animal system, but peculiarly marked when the function of inspiration or expiration is unusually active or disturbed. Strong mental emotions, whether exciting or depressing, greatly disturb the respiratory functions, and, as a necessary consequence, the circulatory system.

The author, in the continuation of his paper, examines respiration in its two acts, of inspiration and expiration, under various conditions; and endeavours to prove that the phænomena of syncope and palpitation of the heart, referred by physiologists to the direct influence of the brain, arise from modification of the respiratory organs.

On the Cause of Death from a Blow on the Stomach, with Remarks on the means best calculated to restore animation suspended by such accident. By G. C. Holland, *M.D.*

The occurrence of death from a blow on the stomach has not in modern times received any full or satisfactory consideration. The cause of this phænomenon is usually referred to a shock communicated to

the nervous system, by which the action of the heart is arrested. The primary impression is considered by some to be made upon the semilunar ganglion, but the evidence adduced, Dr. Holland thinks, is wholly inconclusive. In the absence of satisfactory proof there is great reason to institute a more rigid and cautious examination; and for this purpose the author first attempts to determine the sources of nervous energy to which the heart is indebted, as well as the various degrees of dependence on each. After applying these data to the various forms in which the notion of the influence of the blow on the semilunar ganglion is developed by different writers, the author proposes his own views on the subject.

"In entering upon the inquiry, the first step was to determine the important organs peculiarly liable, from their situation and functions, to be deranged by a blow on the stomach. These were the aorta and the vena cava ascendens, which, from their situation, and the ample space they occupy immediately where the spine becomes prominent after quitting the chest, solicit a careful examination. The pit of the stomach is unquestionably the situation where these large and important vessels are alone liable to severe functional derangement from a blow: above this point they are securely protected by the parietes of the chest, and below it by the mass of the abdominal viscera. A knowledge of the mode in which one of these vessels is liable to be influenced, will explain the cause of death. A blow in this situation has necessarily a tendency, whether it strike the artery or vein, to urge the circulating fluid towards the heart. Nature, by means of the semilunar valves, has prevented the frequent occurrence of such an accident, but the violence of the blow is quite sufficient to overcome the obstacle or barrier to the retrograde motion of the blood. The fatal result, is perhaps to be referred to the *sudden propulsion of arterial blood into the left ventricle*, and not to the greater force with which the venous blood may possibly be returned to its destination. Death would not be likely to occur from the latter circumstance, as the blood would be transmitted in its ordinary direction. The arterial blood, on the contrary, is driven in a retrograde course with considerable violence into the left ventricle."

The correctness of this explanation of the cause of death is discussed at length by the author, and compared with phænomena accompanying a blow in the region of the carotid artery. The plan of treatment, he observes, is obviously pointed out, viz. "to rouse the action of the heart, and this is perhaps best accomplished by artificial inflation, which by improving the qualities of the blood, gives it the power of stimulating the cavities of the left side of the heart. Galvanism, or electricity also, applied to the region of this organ, is well calculated to excite its contractions, and if only fully called into play, the obstacles previously existing would probably be removed, and the heart might gradually but slowly resume its important functions. Friction with stimulating embrocations along the spine and over the whole of the anterior part of the chest must not be neglected if recovery appear doubtful. The application of warmth to the feet, or their immersion in hot water, may

be useful in diminishing congestion, and thereby may co-operate powerfully with other remedies. Internal stimulants may be employed with advantage on the revival of the vital powers; and when these are somewhat invigorated, general or local bleeding may be an invaluable adjunct."

Experiments on the Connexion between the Nerves and Muscles. By WILLIAM HARRIS MADDEN, *M.D.*

The author wishing to contribute to the satisfactory settlement of the questions relating to the connexion of nerves and muscles, first proposes to show, in opposition to several preceding writers, that narcotics do not in all cases produce any appreciable effect upon the contractile organs; that sedatives applied to nerves *exclusively* are absolutely inert; and that muscles exhibit distinct signs of irritability *long after* the nerves have lost their power of exciting them. The experiments which are adduced in proof of these points were made upon frogs, which were killed by injecting tincture of opium into the stomach and intestines, by introducing essential oil of bitter almonds into the mouth, or by destroying the brain and spinal cord. The experiments were made upon the heart, voluntary muscles generally, and amputated legs,—whose nerves, properly dissected, were immersed in a solution of opium, or for comparison in pure water. Galvanic stimuli were applied to the muscles or to the nerves alone; and, as a result of the whole investigation, the author observes, "When we see that narcotics have by no means generally a destructive influence over irritability; when we see that, applied to nervous trunks alone, they produce no change upon the muscular fibre; when we observe that nerves cease to have any power of exciting contractions long before the muscles themselves have lost their irritability (as all the experiments most distinctly show); when we remember that the number and size of the nerves distributed to any organ bear no proportion whatever to its irritability; that many muscles are utterly insensible to any irritation of their nerves; and that a muscle whose nerve has been divided can recover its exhausted irritability in as short a time and as perfectly as one whose nerves have been uninjured;—we shall, I conceive, feel the want of far more extended and conclusive evidence, before we can assent to the doctrine which believes muscular contractility to be in all cases dependent upon nervous influence."

Of Disordered Conditions of the Human Body caused by the presence of Urinary Salts, although not amounting to Gravel or Stone. By *Sir* JAMES MURRAY, *M.D.*

The object of this paper was to show that "the same acid, alkaline, or neutral products, which in some instances constitute sand or calculi, do in others prevail to excess in the constitution, in a liquid or diffused state; and that they thus give rise to a series of nervous and

other diseases of irritation, caused by acrimony and elementary derangement set up by the presence of urinary or other untoward impregnations in the blood and lymph."

In proof of this proposition it is stated, that certain minute crystals lately observed in various tissues of the human body, have probably resulted from the deposition of urinary salts, when their elements have been evolved in excess at some previous period, and that in some cases these crystalline particles have irritated the nerves of sensation and motion. Crystals were found by the author in the tissues investing the principal nerves of the testes, in a case of neuralgia; by Professors Harrison and Apjohn in the membranes of the alimentary canal; and since, by other observers, in the heart, brain, stomach, and other organs and tissues. The author adds the case of crystals found in a thumb afflicted by tic-douloureux. The crystals examined by Dr. Apjohn were composed of earthy phosphates, but those found in Sir J. Murray's dissections afford traces of uric or lethic salts. In cases of impetigines, tinea capitis, lepra, &c., the scales were found to contain urinary salts, and the ichor of ill-conditioned ulcers contained several saline qualities of the urine. The author attributes these and other phænomena to the reabsorption of urine from the bladder into the circulation; the lymph thus becoming saturated with foreign ingredients, it will be easy to account for the generation of crystalline scales in the tissues.

The author considers the opinions expressed by physiologists as to the origin of the saline ingredients found in the solids and fluids; notices the explanation which his researches appear to afford concerning violent local pains unaccompanied by inflammation or heat; particularizes some of the excretions which, when in excess, cause acrimony of the fluids, irritability of the solids, and perverted combinations of various elementary atoms in the animal economy; and suggests the employment of acid or alkaline remedies by the stomach or by baths, according to the indications observed in each case. (See, for a preliminary paper, the Dublin Medical Journal, 7th July, 1836).

Sir James Murray exhibited apparatus for varying the atmospheric pressure on the whole or a part of the body. (See Reports of the Association, vol. iv. p. 96.)

On Cholera. By Dr. Mackintosh.

The facts which Dr. Mackintosh stated regarding the condition of the organs of the body under the influence of cholera, were supported by a great number of preparations and drawings, the fruit of 300 dissections in cases of cholera in the first year of its appearance in a malignant form.

On Morbid Preparations relating to Dysmenorrhea. By Dr. Mackintosh.

On Diseased Lungs from Sand respired. By Dr. JOHN MACKINTOSH.

In this communication, the injurious effects arising from the deposition of particles of stone in the lungs were illustrated by the case of a mason employed in the Cragheith Quarry.

On the Contagiousness of Cholera. By J. G. SIMPSON.

On some Crania found in the Ancient Mounds in North America. By Dr. WARREN, *of Boston, U.S.*

From an examination of the crania found in some of the numerous earthworks forming lines, pyramids, and platforms, which are scattered over the country, from the lakes of Canada to the Gulf of Mexico, Dr. Warren infers that this whole region was once occupied by a race of men differing from the North American Indians as well as from any known people of the old world, but apparently *identical* with the ancient Peruvians, and having much *resemblance* to the Hindoos.

Ornaments and utensils have been discovered in the mounds which bear a great resemblance to articles of the same description seen in Hindostan. On these facts the author founds his opinion that the ancient Peruvian people were the remains of a great race of men dispossessed of their original seats by the North American Indians; and notices as a probable hypothesis, that America was peopled from more than one point of Asia, the ancient Americans having passed from the southern parts of Asia, but the existing Indian races from the north of that continent.

A Critical Analysis of the different Methods that have been adopted for determining the Functions of the Brain. By Dr. EVANSON.

In this communication the author endeavoured to place before the Section a correct general view of the progress hitherto made toward a solution of the question, "What are the functions of the brain?" Dissection of the brain, he observed, has failed to give us a knowledge of its functions; the removal of parts of the brain in living animals has led to remarkable but not perfectly consistent results; the study of the brain in a diseased state had revealed but few and determinate relations between its parts and affections of definite portions of the body; nor has the comparison of the central mass of man with that of animals, in respect of absolute magnitude, proportion to the body, to the spinal marrow, or the bones of the face, (Camper's facial angle,) furnished any perfectly general law, by which the degree of intelligence manifested by the animal may be connected with a particular property of the entire brain. Dr. Evanson then explained the method of induction adopted

by Dr. Gall; who, viewing the brain as a complex organ, and contemplating it both in health and disease, proposed to discover the use or function of each part of the brain, by comparing the relative development of these parts in the same brain, and in the brains of different persons, with the intellectual and moral powers and animal propensities manifested in the individuals.

An Experimental Investigation into the Glosso-pharyngeal, Pneumogastric, and Spinal Accessory Nerve. By Dr. John Reid.

This communication, which was but a short epitome of some lengthened observations which Dr. R. had drawn up on this subject, embraced the principal results which he had deduced from an extensive series of experiments, performed by himself, upon those complicated and important nerves generally included under the eighth pair.

Glosso-pharyngeal.—The experiments on this nerve were all performed on dogs, and were twenty-seven in number. Seventeen of these were for the purpose of ascertaining if it were to be considered a nerve both of sensation and motion, and what are the effects of its section upon the associated movements of deglutition and on the sense of taste. The other ten were performed on animals immediately after they had been deprived of sensation, with the view of satisfying himself more thoroughly how far it is to be considered a motor nerve. The most remarkable effect witnessed in these experiments was an extensive convulsive movement of the muscles of the throat and lower part of the face, on irritating this nerve in the living animal, provided the irritation was applied to the trunk of the nerve before it had given off its pharyngeal branches, or to one of the pharyngeal branches separately. These movements were equally well marked when the nerve was cut across at its exit from the cranium and its cranial end irritated, as when the trunk of the nerve and all its branches were entire. The conclusions drawn from a review of the whole experiments were these: —That this is a nerve of common sensation. That mechanical or chemical irritation of this nerve before it has given off its pharyngeal branches, or of any of these branches individually, is followed by extensive muscular movements of the throat and lower part of the face. That the muscular movements thus excited, depend not upon any influence extending downwards, along the branches of this nerve to the muscles moved, but upon a reflex action transmitted through the central organs of the nervous system. That these pharyngeal branches of the glosso-pharyngeal nerve possess endowments connected with the peculiar sensations of the mucous membrane upon which they are distributed, though we cannot pretend to speak positively in what these consist. That this cannot be the sole nerve upon which all these sensations depend, since the perfect division of the trunk on both sides, if care be taken to exclude the pharyngeal branch of the par vagum, which lies in close contact with it, does not interfere with the perfect performance of the *function of deglutition.* That mechanical or chemi-

cal irritation of the nerve immediately after an animal has been killed, is not followed by any muscular movements, provided that care be taken to insulate it from the pharyngeal branch of the par vagum; and here, again, an important difference between the movements excited by irritation of the glosso-pharyngeal and those of the motor nerve is observed; for, while movements produced by the irritation of a motor nerve, such as the pharyngeal branch of the par vagum, continue for some time after the functions of the central organs of the nervous system have ceased, those from irritation of the glosso-pharyngeal are arrested as soon as all decided marks of sensation disappear. That the sense of taste is sufficiently acute after the perfect section of the nerve on both sides, to enable the animal readily to recognize bitter substances. That it may probable participate with other nerves in the performance of the function of the sense of taste, but it certainly is not the special nerve of that sense. That the *sense of thirst* does not depend entirely upon this nerve.

Pneumogastric or Par Vagum Nerve.—From the results of thirty experiments upon the par vagum, he is convinced that severe indications of suffering are induced by pinching, cutting, or even stretching this nerve, in almost all those animals operated on. In several experiments, in which the trunk of the par vagum was compressed by the forceps for a few moments, it was observed that in some of these cases powerful respiratory movements were thus produced, and were followed by struggles, yet no tendency to cough, and no act of deglutition which could be fairly attributed to this cause.

Pharyngeal Branches of Par Vagum.—From seventeen experiments performed on dogs, either when alive or immediately after being deprived of sensation, he concludes that these are the motor nerves of the constructors of the pharynx, the stylo-pharyngeus, and palatine muscles; and that the sensitive filaments of these nerves must be comparatively few, if, under ordinary circumstances, they exist at all. Section of the pharyngeal branch of the par vagum on both sides, was followed by very considerable difficulty of deglutition, in which the food appears to be forced through the passage bag of the pharynx by the powerful movements of the tongue, and of the muscles which move the hyoid bone and larynx.

Laryngeal Branch of the Par Vagum.—On irritating the superior laryngeal nerve by galvanism, or by pinching it with the forceps, when the glottis was exposed to view, no movement of the muscles which dilate or contract the aperture of the glottis is observed. Upon looking at the interior part of the larynx, upon which the external laryngeal branch of this nerve is chiefly distributed, vigorous contractions of the cricothyroid muscle, by which the cricoid cartilage is approximated to the thyroid, were always seen. On irritating the inferior laryngeal, obvious movements of the muscles which dilate and enlarge the aperture of the glottis followed. In some cases these movements were very vigorous, and it was observed that these did not produce an enlargement of the glottis, but, on the other hand, the arytenoid cartilages were approximated, so as in some cases to shut completely the aperture

of the glottis. It was also distinctly observed, that the only outward movements of the arytenoid cartilages were merely produced by their return to their former position after they had been carried inwards.

From these experiments it was concluded, that all the muscles which move the arytenoid cartilages receive their motor filaments from the inferior laryngeal or recurrent nerves; and as the force of the muscles which shut the glottis preponderates over that of those which dilate it, so the arytenoid cartilages are carried inwards when all the filaments of one or both of these nerves are irritated.

These experiments also show us, that one only of the intrinsic muscles of the larynx receives its motor filaments from the superior laryngeal, viz. the cricothyroid muscle, and that, consequently, the only change which the nerve can produce on the larynx as a motor nerve, is that of approximating the cricoid cartilage to the thyroid; in other words, of shortening the larynx. We shall see how far this view is supported by the subsequent experiments upon the living animal.

The superior laryngeal nerve was cut on both sides in two dogs and one rabbit, and these animals readily swallowed both solids and fluids, without exciting cough or the least difficulty of breathing. The lungs of these animals were carefully examined after death, and none of the food taken could be detected in the air-tubes. In several animals the superior laryngeals were first cut, and the inferior laryngeals immediately afterwards; and it was ascertained that the previous division of the superior laryngeal did not prevent the difficult breathing, and symptoms of suffocation, which not unfrequently follow the division of the inferior laryngeal nerves, especially in young animals.

To procure still more positive assurance of the effect of section of the different laryngeal nerves upon the movements of the glottis, these four nerves were exposed in a full-grown cat, and the larynx was then dissected out, and brought forward, without disturbing the nerves. After watching for a little the vigorous movements of the muscles of the glottis, seen during the struggles, crying, and increased respiratory movements of the animal, the inferior laryngeals were then cut across, and instantly all the movements of the muscles of the glottis ceased, and the arytenoid cartilages assumed the position in which they are found after death. The superior laryngeals were then cut, without effecting the slightest enlargement, or any other change, upon the glottis. As the arytenoid cartilages were now mechanically carried slightly inwards during the rushing of the air through the diminished aperture of the glottis in inspiration, by which this aperture was still farther contracted, its edges were kept apart with the forceps until an opening was made into the trachea to prevent the immediate suffocation of the animal.

The glottis was brought into view upon another cat, as in the preceding experiment, and the motions of the muscles of the glottis were again watched for a short time. The superior laryngeals were then cut, without diminishing in the least any of the movements of the arytenoid cartilages. The sides of the glottis were approximated, as in crying, so as to form but a narrow fissure; and in struggling the aper-

ture became completely closed, in the same manner as when the superior laryngeal nerves were uninjured. It must be at once obvious, that these experiments are completely subversive of the statement that the inferior laryngeal supplies those muscles only which open the glottis, while the superior laryngeal nerves furnish the motor filaments to those muscles which shut the glottis; they also illustrate, in a very satisfactory manner, the cause of the dyspnœa in some cases where the inferior laryngeal nerves are cut or compressed.

Dr. Reid has also satisfied himself, that when any irritation is applied to the mucous membrane of the larynx in the natural state, that this does not excite the contraction of these muscles by acting directly upon them through the mucous membrane, but that this contraction takes place by a reflex action, in the performance of which the superior laryngeal nerve is the sensitive, and the inferior laryngeal is the motor nerve. He has also satisfied himself that the muscular contractions of the œsophagus are not called into action by the ingesta acting directly as an excitant upon the muscular fibre through the mucous membrane, but by a reflex action, part of the œsophageal filaments acting as sensitive, and others as motor nerves.

Spinal Accessory.—In seven dogs this nerve was cut on one side, without affecting the ordinary voluntary movements of that side of the neck. In several animals a weak dose of prussic acid was given after the nerve had been cut on one side. In several cases this was followed by prolonged, forcible, and regular respiratory movements, after the animal had been deprived of all consciousness and voluntary motion. In three of these cases distinct movements of contraction and relaxation were observed in the exposed sterno-mastoid muscles, synchronous with the other muscles of respiration. The contractions were perhaps weaker on the side on which the spinal accessory had been cut.

Observations on the Structure of the Sacrum in Man and some of the Lower Animals. By HUGH CARLILE, *M.B.T.C.D.*

Mr. Carlile exhibited to the Section several anatomical preparations of the human sacrum in different states of growth, in which the separate formation of the lateral parts, consisting both of *ribs* and of *transverse processes*, was distinctly shown. The analogous structures in certain of the Saurian and Chelonian reptiles were exhibited by means of preparations and drawings; and the errors of descriptive anatomists on these subjects were pointed out. Mr. Carlile showed that some of the Saurian reptiles afford the best examples of distinct and well-developed sacral ribs, although this peculiarity in their structure has wholly escaped the observation of previous anatomists. In these animals the sacral ribs are two in number on each side; the anterior being articulated to the bodies of the last dorsal and the first sacral vertebræ, and connected to their inter-vertebral substance—the posterior to the last sacral and first caudal vertebræ. In the human sub-

ject the sacral ribs are *four* on each side; and they remain in a separate and distinguishable state until the age of from three till seven years, after which period they are all, except in rare instances, consolidated, along with the bodies and transverse processes of the corresponding sacral vertebræ, into a single mass. The os ilium in the fœtal state, and for some years after birth in the human subject, is connected to only *two* of the sacral ribs, a fact which is consistent with the imperfect development at this period of the lower extremities, and with the disposition at an early age to walk on all fours; and which affords an additional example to those already known, of the resemblance which prevails between the temporary forms of certain parts of the human body, and the permanent dispositions of corresponding parts in animals of the lower classes. In many of the quadrumana of quadrupeds and reptiles, *two* is the number of sacral ribs constantly in opposition with the os ilium. In the human subject, at a more advanced period of life, the os ilium at each side is connected by a cartilaginous intermedium to the extremities of *three* sacral ribs: in one instance, in the skeleton of a negro, Mr. Carlile observed it conjoined to *four*. This communication was terminated by some observations on the skeleton in some of the Chelonian reptiles. Mr. Carlile considers that in the *Testudo Græca* there are *two* sacral *bones*, one for the anterior, and one for the posterior extremities; while in the *Testudo Mydas*, whose anterior extremities are moved with much freedom, and through considerable extent of space, the anterior sacrum is wanting, and the scapula is connected to the rest of the skeleton, much in the same manner as in birds and some quadrupeds.

Mr. Carlile exhibited two examples of remarkable malformations of the cerebellum in the human subject. In one the size of the cerebellum was not more than one sixth of the usual magnitude, and possessed internally an extremely deficient structure. The person, a female, was idiotic; the genital organs were very fully developed; and there was evidence that sexual intercourse had taken place.

The second example was one in a male adult in whom more than the half of the cerebellum was wanting, the left hemisphere and the vermiform processes being deficient by a congenital malformation. The person was deaf and dumb, but possessed moderate intellectual capacities. His muscular system was well developed, and he enjoyed the complete use of his limbs and other muscular organs. The organs of generation were also well formed.

Practical Observations on the Causes and Treatment of the Curvature of the Spine, with an Etching and Description of an Apparatus for the Use of Persons afflicted by the Disease. By S. HARE, *Surgeon, Leeds.*

Confining his remarks on the origin of curvature of the spine to one of three causes which he assigns, viz. impropriety of dress, want of free exercise, as being chiefly instrumental in producing lateral curvature, which is of most general occurrence; the author demonstrated the manner in which the right shoulder is elevated, and the left shoulder depressed in females of the higher and middle classes, by the injurious tightening of the stays.

For correcting curvature of the spine the author employs an inclined board, 6 feet 6 inches long, furnished with pullies at each end, over which weighted cords pass, so as to pull in opposite directions, a head strap, and two shoulder straps, two ankle straps, and an (occasional) iliac strap. There is an apparatus for compression on the sternum appended to the inclined plane. The author particularly notices that the weights used must on no account be such as to inconvenience the patient, unless the medical adviser have some particular reason for so increasing them.

On the Order of Succession of the Motions of the Heart. By O'BRYAN BELLINGHAM, *M.D. of Dublin.*

If we lay bare the pericardium in a frog (there being no necessity to open it) without causing the loss of much blood, the following series of motions will be observed. The contraction of the auricles; then the dilatation of the ventricle; and if we place our finger on it at the instant we feel the impulse; immediately and quickly following the dilatation comes the contraction of the ventricle, without any impulse; then follows the interval of repose during which the auricular contraction again commences.

The time occupied by the diastole of the ventricle is longer than that of its systole, and the interval of repose is about equal to the systole, The apex of the heart did not strike the finger either during the diastole or systole of the ventricle, but the anterior surface of the ventricle during its diastole communicated an impulse to the finger. In some instances, indeed, when the pericardium was partially opened, and the animal struggled much, the apex of the heart was carried forward during the second motion, or its systole; but when the animal remained quiet, nothing of the kind occurred, the ventricle in its systole contracting from the angles (which its base makes with the auricles) toward its centre, and becoming smaller.

The author compares these results with the motions of the heart of man, as given by Dr. Hope, from which they differ, both as regards the order of succession and the duration of the motions.

A Descriptive and Statistical Report of the Epidemic Influenza, as it occurred at Bolton-le-Moors, in the Months of January, February, and March, 1837. *By Dr.* Black.

In this Report the author gives, first, a *résumé* of the general symptoms, with a notice of those more peculiar pathognomical characters which distinguished some of the more intense cases; and secondly, and principally, directs attention to that view of the epidemic which relates to meteorology, medico-vital statistics, and mortality.

The following extract is from the second portion of this elaborate paper:—

To the medical philosopher the extent and intensity with which this late epidemic bore upon the population of the country, along with the ratio of mortality which marked its progress, as well as the meteorologic state of the weather which preceded and accompanied its march over the kingdom, are subjects of great and historical interest, especially when they are compared with the nature and progress of former epidemics of a similar character. For the purpose of elucidating these important and relative matters, as far as the disease appeared and prevailed at Bolton, I have obtained a correct register of the weather in its principal meteorologic conditions, for the months of January, February, and March, during which period the epidemic appeared, prevailed, and finally decayed in that town and its vicinity. To this register, for which I am indebted to Mr. H. Watson, an intelligent chemist of Bolton, I have added a column exhibiting a nosometric scale of the epidemic's rise, maximum intensity, and decay in the place. This column has been constructed from the several lists of fresh cases of the influenza that were daily entered and kept by three of the principal practitioners of the town and myself; which separate entries for each day, being added together, gave a ratio corresponding to 100 as the maximum intensity on the 3rd of February. To this table I have also subjoined a register of 420 burials at the parish church, Bolton, at which place about nine-tenths of all dying in the borough are interred. I have therein, moreover, stated the several ages, in quinquennial periods, at which the individuals died after the fifth year, with the several amounts and ratios during the late epidemic season, as well as the averages during the same months of the five previous years. (Vide the Tables.)

From the Meteorological Register it is seen that, during the first two weeks of January, the temperature was very irregular, varying in the mean of morning, noon, and night, from 47° 3 to 27° 3, while the barometer was gradually falling from 30·27 to 29·17, and snow, hail, rain, and fine weather in turns prevailed. The epidemic during this period had scarcely made its appearance, and except it had more manifestly done so, the few cases of suffocative catarrh and atonic bronchitis that occurred would have been attributed to an endemic or sporadic origin. With the 14th day of the month commenced a week of fair weather, with a steadier and milder temperature; but after a very sudden rise, there took place a declining state of the mercurial

column, which reached its lowest depression of 28·88 on the evening of the 21st, while the dew point nearly approximated the mean temperature. Contemporarily with this lowest state of the atmospheric pressure on the 21st commenced the full and rapid invasion of the epidemic, similar to some mighty morbific wave that was sweeping over the country—sudden in its attack, but more lingering in its departure. As the disease increased the temperature fell, for seven days, with continued rain or snow till the end of the month, but the barometer on the whole gradually rose until it attained 30·10 on the morning of the 4th of February. On the day previous to this the disease had reached its maximum intensity, having, in the course of a fortnight, laid the whole population, with very trifling exceptions, under its morbiferous influence, which extended from the merest *malaise*, or slight catarrh, to the most deadly impression on the functions and organs of life. After this culminating point of the epidemic, it gradually lessened in the number of its cases, though not in the severity of many individual instances. About the 9th of February a slight resumption of intensity appears on the scale, and this was occasioned by the disease becoming a little more rife in the country after it began to subside in the town; but the whole cases of fresh attack were reduced to a very small comparative number on the 21st, when the epidemic may be said to have passed over the place, after having left, and yet then leaving, many a fatal footstep behind. Cases assuming not all the well-marked traits of the early epidemic, but the more varied, obscure, and modified characters of rheumatism, neuralgia, febricula with headache, and bowel attacks with lumbar pains, continued to appear during the remainder of the month and the first part of March, but all these cases may be fairly charged to that constitutional taint or diathesis which the epidemic had produced. In addition to what the register denotes of the weather during the three months mentioned as being inclement, cold, and unsettled, with several falls of snow; it may be noticed, the invasion of the epidemic was preceded and attended by easterly and southerly winds, while the atmosphere was much loaded with moisture. This high point of saturation may be frequently observed to have taken place during the prevalence of the epidemic, for the dew point will be seen for several days to be as high, if not higher, than the mean temperature for the day. This anomaly in part arises from the dew point being only taken once in the day at noon, while the temperature was not only taken at that hour, which at all times would be higher than the dew point, but this higher temperature would be brought down in the scale by the lower averages of morning and night.

From Dr. Heberden's Analysis of the Bills of Mortality in London, as published in the *Medical Gazette*, 8th April, 1837, it appears that the epidemic commenced about the 10th of January, had attained its height of mortality on the 24th, and ceased after six to seven weeks from its appearance. Dr. Clendinning, in his Report of the Marylebone Infirmary, makes the epidemic to appear on the 1st of January, to be at its maximum prevalence about the 20th, and to have ceased

in five or six weeks. The apparent difference of these two reports from the same place arises from the one recording the deaths in consequence of the disease, and the other stating the number of admissions into the infirmary—thus showing that the date of the greatest number of deaths will consequently follow, at a more or less distance of time, the date of the highest prevalence of the disease as to general seizure.

In adverting to the more interesting register of the burials during the prevalence of the epidemic, it is seen how much the mortality of the place was increased, in comparison with the average mortality during the same months of the five previous years. The increase on the whole three months is equal to 45 per cent.; and for the month of February alone it amounted to 160 per cent. Of the 420 deaths, 205 were males and 215 females, while the sexual proportion of our annual deaths is as 109 males to 100 females. Nearly the half, 208, of the whole 420 deaths were under twenty years of age, while the half of the annual deaths during the five previous years were under three years and ten months. The augmentation of this mortality must entirely be attributed to the influenza, and I even think a good deal more is owing to the epidemic, as very few serious diseases took place and were fatal but what the prevailing epidemic was connected with; and it was often the sole destroyer of patients lingering under chronic ailments or diseases, necessarily, yet otherwise not so speedily fatal. The mortality during this period bore more upon the aged and infirm than upon the young and infants, who generally form the great amount of our deaths, and decide, according to the rise and fall of their mortality, the annually ranging rate of our total deaths to the population. Under one year 21·9 per cent. of the whole 420 died during the epidemic, while the average this age for the same months of the five previous years was 26·6 per cent. The same diminished proportion is observed during the second year of life. These ratios in favour of early life, during the prevalence of the epidemic, continue until we reach the thirtieth year, after which, it is seen, that the ratio for adult life augments very much, contrary to what is observed in the average course of our mortality. For instance, between the years 45–49, the ratio of deaths to the whole during the epidemic was 6·2 per cent., while, at the corresponding ages in the five previous years, it was only 2·7 per cent. Nearly the same disparity obtains at the quinquennial period of sixty-five to sixty-nine; and through all the advanced years of life, mortality is seen to have borne with double and treble force, compared with the ordinary rate at those periods during the former years.

The few reports which I have seen from other parts of the united kingdom coincide in this high rate of mortality affecting the advanced years of life during the prevalence of the epidemic, and the comparative immunity which those of younger years enjoyed, at least, from its fatal consequences. From a Report, by Dr. Clendinning, on the admissions at the Marylebone Infirmary during the six weeks that the epidemic prevailed, it appears, that though the admissions were seventy from

birth upwards to ten years of age, and which included twenty-one cases of influenza, the deaths were only 57 per cent.; between ten and twenty the admissions were seventy-three, including thirty-five cases of influenza, and the deaths were only about 7 per cent.; between the ages of twenty and thirty the deaths to the whole admissions were 13 per cent.; between thirty and forty the proportion was 25 per cent.; between forty and fifty it was 31·5 per cent.; between fifty and sixty it was 36 per cent.; and between sixty and seventy the ratio was still 31 per cent.; the whole admissions being in the above period 465, more than half of which were influenza cases; and the deaths were 98, or 22 per cent.

From a report made by Dr. Graves, in a late number of the Medical Gazette, of the numbers interred at Prospect Cemetery, Glasnevin, during the months of December, 1835, and January, February and March, 1836, compared with the same months in 1836 and 1837, it appears that the burials were augmented from 1501 to 2248, or 33·2 per cent. of an increase during the influenza.

From the limited observations and register which I have had the indulgence of laying before the Section, it is seen what an extensive and destructive pestilence has swept over the kingdom, which has about doubled the ordinary rate of mortality, where it in any characteristic force prevailed, and thus anticipated for some months the forthcoming victims of death, while it threw a subsequent pause over the regular march of disease and mortality. This retardation has been very generally observed in the low rate of disease and mortality which occurred during the four months succeeding the epidemic.

If a collection of reports, contemporaneous and similar to the one I have submitted, could have been obtained from the several districts and towns throughout the kingdom, the date of the rise, progress, and culmination of the epidemic might have been traced and ascertained in its march throughout the country, and most probably some meteorological conditions would have been found so general and constant as might have led to some fair deductions of the co-efficients of its appearance and intensity, or of its utter irrespectiveness to all such physical conditions; but in default of such strict elementary documents, we are left to speculate about many causes in the earth and atmosphere, as productive of the epidemic, according as a theoretical ingenuity from limited observation may indulge in, but which may be far from the legitimate and satisfactory deductions of medical philosophy.

A Meteorological Register for January, February, and March, 1837, with a Nosometrical View of the Epidemic Influenza during the same months, as observed at Bolton-le-Moors.

1837. Jan.	Mean of Morning, Noon, and Night. Therm.	Barom.	At Noon. Dew-point.	Evaporation.	Fall of Rain.	Weather.	Nosometrical Scale of the Epidemic Influenza. Maxm. Intensity=100.
1	30°·3	30°·27	30°	....	....	Fair all day	...
2	32·3	30·12	31	....	....	Very foggy	·1
3	40·	30·02	38	....	....	A little rain A.M. and P.M.	...
4	38·3	30·02	39	....	....	Fair	...
5	36·	29·62	35	....	....	Fair	...
6	39·3	29·19	38	....	....	Rain all day, some hail P.M.	·5
7	38·3	29·37	38	....	....	Rain and a little hail A.M. and P.M.	...
8	38·7	29·82	35	....	....	Rain at night	...
9	47·3	29·68	46	....	....	A little rain A.M.	1·
10	37·3	29·62	38	....	....	Fair	...
11	27·7	29·89	27	....	....	Fair	1·5
12	34·3	29·47	28	....	....	Snow A.M. Snow and rain P.M.	...
13	40·7	29·17	38	in 16	in 16	Rain in the morning	2·
14	33·7	29·94	32	days,	days,	Fair	2·3
15	34·	30·15	30	0·15 in.	2·44 in.	Fair	3·4
16	38·7	30·05	37	....	....	Very foggy, P.M.	4·6
17	40·	29·98	38	....	....	Fair	9·1
18	38·	29·82	35	....	....	Fair	14·
19	37·7	29·64	35	....	....	Fair	18·
20	35·	29·46	32	....	....	Fair	25·
21	37·	29·25	33	....	....	Rain at night	30·
22	44·	28·94	43	....	....	Rain all day	40·
23	45·3	29·02	43	....	....	Rain all day	42·
24	41·7	29·30	41	....	....	Rain A.M.	50·
25	41·	29·45	40	....	....	Rain all day	56·
26	39·3	29·53	37	....	....	Fair	71·
27	37·	29·68	36	....	....	Rainy at night	75·
28	33·	29·73	33	....	....	Snow at night, and a little A.M. and P.M.	80·
29	32·	29·57	30	in 15	in 15	Snow all day	90·
30	36·	29·48	34	days,	days,	Snow A.M.	92·
31	41·7	29·61	40	0·09 in.	1·10 in.	Rain P.M.	93·
Max.	49°·	30°·31	° ...	Total. 0·24 in.	Total. 3·54 in.		
Min.	25·	28·88	...				
Mean	37·5	29·638	35				

FEBRUARY.

Feb.	Mean of Morning, Noon, and Night. Therm.	Barom.	At Noon. Dew-point.	Evaporation.	Fall of Rain.	Weather.	Nosometrical Scale of the Epidemic Influenza. Maxm. Intensity=100.
1	41·3°	29·79	40°	....	....	Rain at night........	95·
2	43·3	29·99	41	....	....	Fair all day	98·
3	41·3	30·03	40	....	....	Rain all day	100·
4	41·	30·07	40	....	....	Fair all day	90·
5	37·7	30·01	36	....	....	Rainy A.M. and P.M.	82·
6	41·	29·98	37	....	....	Fair all day	71·
7	41·	29·88	39	....	....	Fair all day	60·
8	43·	29·80	41	....	....	Rain A.M. and P.M.	72·
9	47·	29·83	44	....	....	Some rain at night........	91·
10	49·	29·34	50	....	....	Rain all day, stormy P.M. ...	69·
11	43·3	28·72	50	....	....	Rain and very stormy all day	62·
12	39·3	29·02	37	in 14	in 14	Rain morning and night ...	60·
13	44·	28·82	44	days,	days,	Rain A.M.	55·
14	41·	29·21	40	0·27 in.	2·15 in.	Fair all day	50·
15	43·3	29·62	41	....	....	Rainy P.M.	44·
16	52·	29·65	50	....	....	Fair all day, stormy at night	37·
17	44·3	29·90	44	....	....	Fair all day	36·
18	41·3	29·44	44	....	....	Rain P.M., rain and hail at night	30·
19	38·3	28·95	38	....	....	Rain and a little snow all day, boisterous P.M. ...	23·
20	42·	29·19	42	....	....	Rain at night........	21·
21	41·3	29·19	41	....	....	Rain at night and P.M.	14·
22	41·	29·51	39	....	....	Rain A.M., rain and snow P.M.	9·1
23	39·	29·02	43	....	....	Rain, hail and snow; very stormy P.M. and night.	8·
24	39·	29·64	40	....	....	Fair all day, but boisterous	7·
25	35·3	29·95	35	....	....	Fair all day	6·
26	33·7	29·90	30	in 14	in 14	A little snow P.M.	7·
27	39·3	29·74	40	days,	days,	Rain at night........	4·6
28	38·	29·95	40	0·54 in.	2·25 in.	A little rain P.M.	4·
Max.	56·°	30·10°	°...	Total. 0·81 in.	Total. 4·40 in.		
Min.	30·	28·60	...				
Mean	41·4	29·57	40·9				

MARCH.

March.	Mean of Morning, Noon, and Night. Therm.	Barom.	At Noon. Dew-point.	Evaporation.	Fall of Rain.	Weather.	Nosometrical Scale of the Epidemic Influenza. Maxm. Intensity=100.
1	34°·	30·19	32°	....	....	Fair all day	3·4
2	37·7	30·10	32	....	....	A little rain P.M. and at night	3·5
3	40·	30·08	41	....	....	Slight rain A.M. and P.M. ...	4·6
4	39·	29·95	39	....	....	Fair all day	4·
5	37·3	29·71	39	....	....	Slight rain A.M. and P.M. ...	3·5
6	39·3	29·77	37	....	....	Fair all day	3·
7	40·	29·85	37	....	....	Ditto	2·3
8	42·	29·83	38	....	....	Fair all day, but strong wind A.M. and night ...	2·2
9	45·	29·57	39	....	....	Slight rain P.M. and at night	2·
10	41·7	29·00	40	....	....	Rain P.M. and stormy	1·2
11	36·	28·85	34	....	....	Snow and rain P.M.	...
12	36·3	29·23	35	....	....	Rain and snow at night ...	...
13	36·3	29·85	38	in 15	in 15	Snow A.M.	1·
14	37·	30·17	32	days,	days,	Fair all day	...
15	37·	29·99	33	0·38 in.	0·20 in.	Ditto	1·2
16	40·3	29·92	36	....	....	Ditto	...
17	41·7	30·08	38	....	....	Ditto	...
18	37·7	30·02	37	....	....	Slight sleet at night	...
19	37·3	29·85	33	....	....	A little snow A.M.	...
20	35·	29·78	38	....	....	Snow all day	1·3
21	37·3	29·55	32	....	....	Slight snow the whole 24 hours	...
22	32·7	29·50	32	....	....	Ditto P.M. and at night ...	1·
23	32·7	29·47	34	....	....	Ditto the whole 24 hours...	...
24	34·	29·54	35	....	....	Much snow in the morning	...
25	36·	29·46	35	....	....	Slight rain and snow at night	0·8
26	34·	29·52	34	....	....	Slight snow and hail P.M. ...	0·5
27	32·3	29·66	30	....	....	Ditto all day	...
28	36·	29·47	34	....	....	Heavy fall of snow A.M., snow P.M.	...
29	37·7	29·36	36	in 16	in 16	Snow A.M., hail at night ...	0·1
30	36·7	29·57	36	days,	days,	Fair all day	...
31	36·7	29·64	34	0·25 in.	1·21 in.	A little snow early in the morning	...
Max.	51°·	30°20	°...	Total. 0·63 in.	Total. 1·41 in.		
Min.	26·	28·90	...				
Mean	37·3	296·97	35·5				

Register of 420 Burials at the Parish Church, Bolton, in January, February, and March, 1837, with the average amount of Burials during the same months of the five previous years, and the ratio per cent. buried at the several ages, to the total deaths in the two periods.

Age.	1837. Jan.	Feb.	Mar.	Total Burials for the 3 months.	Ratio per cent. at the several ages to the total Burials for the 3 months.	Average Burials during the same months in the five previous years.	Ratio per cent. at the several ages to the total Burials in the same months of the 5 former years.
Under 1 year	21	50	21	92	21·9	76·6	26·06
1	11	24	7	42	10·	39·8	13·08
2	10	8	2	20	4·8	18·2	6·03
3	1	8	2	11	2·6	8·6	3·
4	3	1	3	7	1·7	9·4	3·24
5 — 9	3	3	4	10	2·4	18·	6·27
10 — 14	5	8	4	17	4·	7·	2·43
15 — 19	4	4	1	9	2·1	6·8	2·36
20 — 24	2	5	6	13	3·	10·2	3·54
25 — 29	2	6	2	10	2·4	9·4	3·26
30 — 34	7	10	1	18	4·3	6·8	2·36
35 — 39	1	5	5	11	2·6	7·	2·43
40 — 44	6	7	3	16	4·	6·8	2·36
45 — 49	8	11	7	26	6·2	7·8	2·07
50 — 54	7	9	3	19	4·5	6·	2·
55 — 59	1	9	3	13	3·	7·8	2·07
60 — 64	2	11	6	19	4·5	11·4	4·
65 — 69	10	11	6	27	6·4	8·6	3·
70 — 74	2	8	9	19	4·5	11·4	4·
75 — 79	5	3	2	10	2·4	4·8	1·66
80 — 84	3	4	2	9	2·	4·	1·04
85 — 89	...	...	...	...	...	2·4	0·83
90 — 94	...	...	...	...	...	0·6	0·02
95	1	...	...	1	0·24	0·2	0·07
100	...	...	1	1	0·24	...	...
Total.........	115	205	100	420	...	...	...
Total average for the 5 previous years.	111·2	79	97·8	...	...	28·8	...

J. BLACK, M.D.

Some Remarks on the Motion of the Blood in the Head, and on the Uses of the Ventricles and Convolutions of the Brain. By Dr. Carson.

This paper relates to three points; 1st, the circulation of the blood through the head; 2nd, to the evolution and regulation of the heat of the head. On the first point little was added to what had been already published by the author. The 2nd head also only contains an extension of that power of generating and reducing heat, possessed by every part of the body to the encephalon.

This subject, the third point, on which the originality of the communication chiefly consisted, explained the contrivances which nature had used to retain all parts of the brain itself, and of its connection within the head in their natural position, both with respect to the parts of one hemisphere of the brain in relation to each other, and to the cranium. As it was contended to be fully proved that the substance of the brain is liable to decrease and enlargement, like every muscular or soft part of the body, in cases of great emaciation or obesity; and as the brain must always occupy the same space, that is, it must always fill the cranium; it was necessary, in these changes of dimensions, to have contrivances for allowing the brain to occupy this space without laceration or undue stretching of the substances and appendages of the brain to their appropriate parts of the skull. These contrivances consisted of two kinds—the ventricles placed in the interior of the brain, and the convolutions on its exterior superficies. The internal ventricles or chambers were receptacles irregularly formed, all connected with each other and with the spinal canal. By these receptacles containing more or less of water, according to the extent of actual brain, the existing quantity of brain was allowed to assume the condition that was fitted to retain its relations. In this office the ventricles were greatly aided by the convolutions of the brain. Had the surface of the brain been smooth and continuous, the superficial parts of the brain would in a case, let it be supposed, of great emaciation, be unduly stretched. This stretching would be unequal, being required to be greater the farther any part of the surface of the brain was distant from the middle. In consequence of this, parts of the brain of a person in full health, and of the same person in a state of emaciation, would be opposed to different parts of the skull. Protuberances of the brain in one case received into depressions of the skull, would, in the other, be opposed to protuberances of the skull, and the nerves and blood-vessels would, in the different cases, have a changed direction, and one altogether incompatible with their functions. To prevent these effects, nature has nicked the external surface of the brain. The convolutions formed by this nicking, in cases of emaciation, have wider interstices between them, and become themselves narrower as the furrows are enlarged, while the ridges are smaller. These enlargements of the furrows cooperate with the ventricles, in cases of greater emaciation, in securing to the changed amount of brain its natural position. The size of the furrows is formed or filled by an increased vascularity and

cellularity in the vessels of the pia mater and arachnoid coat. Protuberances of the brain received into depressions of the skull and the nerves and blood-vessels find their road to their place of exit out of the skull unchanged.

This appears to be one of the most important and indispensable uses of the ventricles and convolutions of the brain.

Abstract of Cases of Laceration of the Rectus Abdominis Muscle, &c. By Sir DAVID J. H. DICKSON, *M.D., F.R.S.E., F.L.S., Physician of the Royal Hospital, Plymouth.*

William Cooper, æt. 37, Royal Marine, was admitted into Plymouth Hospital as a case of pneumonia, or of aggravated influenza, then prevalent, on the 14th January, and after being considered convalescent, was attacked with excessive diarrhœa, and died on the 26th January, 1837. There was no external indication, nor had any suspicion been previously entertained, of his having sustained any injury: but on opening the abdomen, the unusual thickness of its walls attracted attention; and on raising the fascial and tendinous coverings, the left rectus abdominis was found to be torn across, midway between the pelvis and umbilicus, leaving a cavity between the retracted ends of the softened muscle, containing about four ounces of a bloody serous fluid. The superficial cellular tissue was infilated with a gelatinous-looking matter, and the peritoneum beneath had an ecchymosed appearance. A corresponding portion of the right rectus abdominis was also so much softened, as almost to resemble clotted blood. Neither the thoracic nor abdominal viscera exhibited any traces of disease. A man, who had been a shipmate with the patient, stated he had heard of his having met with some accident, though he did not remember of what nature: but neither at the barracks, nor from the surgeon of the ship to which he had belonged in the Mediterranean, who was written to on the subject, could any information be obtained. The latter merely stated, that the man in question had not been in the sick-list for any accident during the time he had been in the vessel.

In another case, the existence of abdominal injury was equally unsuspected. John Brown, seaman, æt. 27, was admitted in a moribund state, from pulmonary apoplexy, and died within twenty-four hours afterwards. Besides pleural adhesions, the lungs, on dissection, were found much diseased; the left lung especially was tuberculated and hepatised, with some calcareous deposits; while the lower lobe contained a very large coagulum of effused blood, from which the fibrine had separated. On opening the abdomen, the knife sunk into a cavity on the left side, containing extravasated blood; and the greater part of the rectus abdominis muscle was discovered to be lacerated, and which was supposed to have been caused by over-exertion in furling sails; but from the absence of the vessel, no further particulars of the case could be obtained.

The writer likewise adverts to other instances, including two or three

subjects who had been hanged, in whom several of the extensor muscles had been torn across, leaving an interspace containing extravasated blood; especially one stout, muscular man, in whom the right triceps, extensor cubiti, and both vasti interni, were completely ruptured; while, in tetanus, cholera, &c., the muscular fibres have been found completely or partially lacerated. And from these and various other instances on record, he is led to infer that such injuries are of more frequent occurrence than is generally imagined.

Sir David Dickson also notices a case of transposition of the cæcum, which was found in the left instead of the right inguinal region; the colon ascending and descending on the same side; and a more recent dissection, where, instead of the ninth nerve on the right side giving off a descending branch, the eighth nerve supplied a compensating branch, having a similar termination and communications as the descendens noni on the left side, the origin and distribution of which were normal.

The paper concludes with the history and *post mortem* appearances of three unusually interesting cases of dropsy. In one of them, a combination of ascites and hydrothorax, the patient was saved from impending dissolution, and his life prolonged twenty-five days, by the abstraction of thirteen pints of fluid from the left cavity of the pleura. In another, the patient lived upwards of six months, during which the operation of paracentesis abdominis was performed fourteen times.

P.S. The officer who recovered after having been twelve times tapped in 1833, (as noticed in the Medical and Chirurgical Journal for January, 1834,) continues in perfect health.

Abstract of a Paper read before the Medical Section of the British Association at Liverpool, on the Physical and Chemical Characters of Expectoration in different Diseases of the Lungs, with some Preliminary Remarks on the Albuminous Principles existing in the Blood. By R. H. Brett, *F.L.S., M.R.C. S., &c.*

The object of the present paper is an attempt to show that the physical and more especially the chemical characters of expectorated matter in different pectoral diseases may assist in diagnosis. The preliminary remarks are on albuminous principles existing in the blood. The serum of blood is looked upon as containing in aqueous solution two if not three modifications of albumen. The globular part, on the other hand, is regarded as made up of solid albumen or fibrine and colouring matter. The albumen in the serum appears to be, 1st, in an uncombined state; 2ndly, in combination with an alkaline base; and 3rdly, in a state capable of undergoing spontaneous coagulation. The results obtained from a physical examination of sputa in different diseases of the lungs leads to the conclusion, that although, at certain stages in different pulmonary affections, the physical character of the sputa varies, still that in consequence of the complication produced by

the occasional passage of one form of lung affection into another on the coexistence of disease in different and distinct parts of the pulmonary structure, the expectoration met with in one form of uncomplicated lung disease, may be found in any other mixed with that peculiar to the part of the pulmonary tissue principally and originally diseased. The appearance of globular bodies in sputa, under the microscope, cannot be regarded as decidedly characteristic of any one form of expectoration, belonging to all and even to healthy saliva, but differing in regard to the extent of globularity in certain affections. From the chemical examination of sputa, it is deduced that they differ from each other, in the proportion of soluble albumen capable of coagulation by heat which they contain, as also in the amount of fixed or non-volatile saline matters. That form of expectoration met with in pituitous catarrh does not contain any free albumen capable of coagulation by heat, and, for equal weight, less saline matter than any other form of sputum; the solid matter also amounts to a very little more than that met with in ordinary saliva, and sometimes even less, and although, for equal weight it contains less solid and saline matter than any other form of sputum, yet for equal weight of dried extract, it contains more than other forms of expectorated matter. The sputa in chronic bronchitis differ from the last noticed principally in containing a small quantity of free albumen, which heat coagulates, in the larger quantity of solid matter contained in it, being double that found in the sputum of pituitous catarrh, in the quantity of saline matter being less in proportion to the solid contents, although, for equal weights of the two forms of expectoration, the difference is not considerable. In acute bronchitis the albuminous matter found in the expectoration probably arises from the presence of a muco-purulent secretion poured out by the inflamed bronchial membrane. Sputum, precisely like the chronic bronchitic variety, occurs also in the different but more especially in the early or middle stages of phthisis, with or without an admixture of softened tuberculous matter; in no disease, however, is free albumen, capable of coagulation by heat, met with in such abundance as in the latter stages of phthisis: the absence of such considerable albuminous impregnation cannot however be taken as clear evidence of the non-existence of phthisical disease, for the latter may exist and the expectoration still be of precisely the same character as that met with in chronic or even acute bronchitis; when on the other hand a large quantity of coagulable albumen is present, the existence of phthisis may be strongly suspected, a small quantity of the albuminous principle only being common to phthisis as well as simple bronchial affections unassociated with tuberculous disease. Genuine pneumonic expectoration always contains coagulable albumen, which appears to be derived from the blood to which this form of sputum owes its peculiar colour. The quantity of solid matter is considerably greater than in any of the preceding forms of expectoration, amounting to more than double that met with in the chronic bronchitic variety. The extremely tenacious character of genuine pneumonic sputum is probably depending upon the existence of a very tough form of mucus resulting

from a very active inflammatory condition of the smaller bronchial tubes. In phthisis the expectoration varies much according to the stage of the disease, and it is only, for the most part, in the latter stages, that it is generally found to differ in a marked manner both as to its physical appearance and chemical habitudes from all other forms of sputa. In the earlier stages of the disease it may be precisely the same as that met with in pituitous catarrh, or other decided bronchitic affections; in the latter stages, however, it will almost always be found at some time or other, to contain large quantities of coagulable albumen, as well as the same principle in the solid form; so that in some instances it scarcely differs in appearance from ordinary pus, of which in fact it mainly consists. The origin of the puriform matter in phthisis is probably from different sources; 1st, from the perfect softening down or fluidification of tubercular deposit; 2ndly, a secretion from the bronchial membrane; and 3rdly, from the secreting lining membrane of tubercular cavities. One thousand grains of phthisical expectoration of a well-marked purulent character, being so diffluent that it might be poured *guttatim* from one vessel to another, possessing a distinct greenish tinge, were analyzed with the following results:—

Water	967·300
Albuminous matter with a little mucus	17·387
Animal matter soluble in alcohol, consisting of fatty matter, and a little extractive	6·177
Animal extract soluble in water	5·840
Salines, consisting of alkaline chlorides, sulphates, and phosphates, earthy phosphatic salts, and oxide of iron. The base of the alkaline salts was chiefly soda, a little potass was nevertheless present	1·813
Loss	1·483
	1000·000

The above exhibits a striking similarity between the puriform variety of phthisical expectoration and actual pus. In both is an abundance of coagulable albumen, in both solid albumen, in both are extractive matters, both contain fatty matter, the same or nearly the same alkaline and earthy salts; and lastly, in both fluids a notable quantity of oxide of iron is found. Phthisical sputa, late in the disease especially, contain a considerable quantity of fatty matter soluble in alcohol and æther, and requiring a higher temperature for its fusion than ordinary fatty matters; other forms of expectoration, particularly that of the chronic bronchitic kind, contain the same substance, but never in such quantity as in genuine phthisical sputa.

That crude tubercular deposit is capable of being converted by the process of softening or fluidification into pus, is rendered highly probable from the chemical nature of hard tubercles as well as that of the same deposit in the most complete state of softening. From a compa-

rative chemical examination of crude tubercle and ordinary fibrine, as well as from the action of re-agents on softened tubercular matter, the following is deduced:—1st, that crude tubercles, as met with in incipient phthisis, do not differ chemically from fibrine or solid albumen; 2dly, that softened tuberculous matter differs not in its chemical habitudes from ordinary purulent matter.

Observations on the Disease called COCOBÆ *by the Africans, or the* ARABIAN LEPROSY; *the* ARAPATTA *of the Caribes of Guiana*; *the* RADESYGE *of Northern Europe*; *all of which appear to be* identical; *and on the Method found most effectual in the Treatment of this Disease. By* JOHN HANCOCK, *M.D.*

The author having long since paid much attention to the leprosy observed in Guiana and the West India islands, among blacks, whites, and aborigines, was surprised to find, by the description given in the Edinburgh Medical and Surgical Journal, vol. xviii., that the radesyge of Scandinavia exhibited exactly the same train of symptoms. He therefore arrived at the conclusion, that these diseases, supposed by the learned writer in the Edinburgh Journal to be distinct, were really identical; and after detailing the characters of the cocobæ, or Arabian leprosy, he states the result of his own observation to be totally opposed to the notion of the cocobæ being in the smallest degree contagious, unless, possibly, under predisposition, and other concurring causes, and in the ulcerative stage.

Unfortunately, in the colonies the disease is considered to be incurable. If attended to early, however, the symptoms may be easily arrested by the use of saline lenitives, with antimonial anodyne diaphoretics, vapour-baths and frictions, bleeding, spare and abstemious diet, and the several means for promoting lymphatic absorption, and all the secretions. The difficulty of the medical treatment in more advanced stages of the disease, is augmented by the aversion entertained for it, and the consequent want of accommodation and assistance.

The author describes the result of his practice in some cases where cures were effected; notices the value of opium, in combination with mercury and antimony, bleeding, saline purgatives, and regulated diet. Among other remedies, he found the *Coonu-paru* useful; and describes bathing as of great and paramount advantage, especially the alternate use of warm vapour and cold effusion.

"The aborigines of Guiana, on noticing the first appearance of the disorder, in general resort to fomentations, tepid and vapour baths; and form a drink of the bark of a tree (*Mouca*), together with the root of a vine termed *Paramaroora*, a species of Cissus, and the bark of the Waiacano (*Guiacum*). This infusion stands to ferment with a portion of honey, and is taken several times a-day: it produces a copious flow of urine and perspiration, and evacuates the bowels withal. They make use also of the bark of the tree Tamootu (a nondescript), both

internally and in fomentations. During this course, they enjoin a strictly abstemious diet, and prohibit the use of animal food in a great measure, especially the use of the *manati*, the *capebaru*, the *arapaima*, and several kinds of fish, which are considered as gross food."

SECTION G.—MECHANICAL SCIENCE.

A Railway Balance Lock, designed for the purpose of Raising or Lowering a Train of Carriages by Horizontal Motion. By GEORGE REMINGTON, *Jun.*

Mr. Remington proposes that the trains should be run on to a stage of wood or iron, and that the stage should be raised or lowered by wheels and axles upon tram-plates or rails, laid in a series of inclined planes made in the walls on either side of the stage; the weight of the stage and train is to be partially counterbalanced by a system of weights, and the requisite power is to be supplied by a stationary engine.

The construction and method of working was explained by reference to a plan and section; and the author thinks that the introduction of this system, both as regards cheapness and despatch, will tend in a great measure to promote the science of railways, which has been so ably introduced, and would extend the system to those places which have been considered almost inaccessible.

The Treffos Pump. By JOHN WILLIAMS, *of Bangor.*

Mr. Williams proposes to keep up a continuous supply of water, whatever may be the relative position of the well and of the pump, by means of an air-tight vessel or chamber, which he calls a "Treffos;" and which is to be filled in the first instance with water through an aperture in the top, the aperture being completely closed before the pump is set in motion. As the piston ascends in the working barrel the water will flow in from the additional vessel; and thus that which is attained imperfectly by use of two or more cylinders acting in succession, may be accomplished in the common house-pump.

On the Expansive Action of Steam in some of the Cornish Pumping Engines. By W. J. HENWOOD, *F.G.S.*

Mr. Henwood gave an account of experiments which he had instituted on the expansion of steam in the cylinders of some reciprocating engines in the Cornish mines. The curved lines described by an indicator were exhibited, and shown to vary, as the pressures and

quantities of steam in the boilers, the sizes of the valves, and the loads of the engines; at least in the early part of the working stroke. The termination of the return-stroke well exhibited the benefit of *expansive* working. The duty per bushel of coal consumed was shown to be from 73 to 86 millions of pounds, lifted one foot high by the consumption of each bushel of coal; and from 870 to 1085 *tons* lifted one foot high for *one farthing of expense.* Tabular statements of the various elements employed, and diagrams illustrative of the conditions of the engines examined, were also exhibited.

The communication of Mr. Henwood gave rise to a lengthened discussion on the duty of the Cornish engines; and Mr. Henwood explained his reasons for thinking that 125 or 120 millions was too high for an average duty. The trial which gave 125 millions was of too short a duration, not more than 24 hours; and no reliance can be placed on short trials, since there may be a considerable reservoir of heat worked out; also the engine may be in a much better condition than can usually be maintained. Mr. Henwood considered that the best duty was obtained from engines having 10 feet stroke in the cylinder and 7 feet in the working barrel, and making from about 5 to 7 strokes in the minute; also that the single-acting do more duty than than the double-acting engines.

On the Mechanism of Waves, in relation to the Improvement of Steam Navigation. *By* JOHN SCOTT RUSSELL, *F.R.S.E.*

Mr. Russell had at previous meetings of the British Association given an account of his investigations in the resistance of fluids to the motion of vessels, and ascertained the law of interference of the wave in modifying the nature and amount of that resistance.

Since the last meeting of the Association, he had extended his observations to a variety of the applications of the principles formerly developed, to certain objects of practical importance, and, amongst others, to the improvement of the navigation of such rivers as the Thames and the Clyde, where steam navigation is extensively carried on. In these rivers it was found that steam navigation was conducted under very great disadvantages, when compared with the open sea. Mr. Russell had investigated the causes of these impediments, and he had found that in shallow water one great impediment to high velocities was the generation of the great wave of translation of the displaced fluid: the effect of this great anterior wave was to alter the position and increase the anterior displacement and resistance of the fluid. The next great impediment to steam navigation consisted in the formation of lateral currents on the side of the vessel, which, having the same direction with the motion of the paddles, had the effect of diminishing the relative difference of the velocity of the paddles and of the fluid, and thus diminish the propelling power of the paddles. The third evil resulting from the use of steam in shallow rivers arose from the stern-wave or posterior surge, by which great injury was done to the banks

of the rivers, and to the smaller vessels navigating the same water. Now it had been fully proved in the course of Mr. Russell's observation. that there was only one mode of materially diminishing all of these evils; that one mode consisted not in widening the rivers as was generally supposed, nor in giving gradual and gentle slopes to the sides of the channel, but in *deepening the river and rendering its sides as nearly vertical as possible.* By this means it had been found that the impediments arising from the formation of the channel were diminished to a very great amount.

The next species of wave generated by a steam vessel is the wave of unequal displacement. This wave was found to arise solely from the form of the vessel. It was this wave which was seen diverging on both sides of the vessel, from the prow towards the stern, and might be seen, arranged in two straight lines, extending to a great distance behind it. This wave might be greatly diminished and almost entirely removed, by giving to the lines of displacement a particular form which Mr. Russell described.

On Improvements in Tidal Rivers. By JOHN SCOTT RUSSELL, *F.R.S.E.*

Mr. Russell renewed the subject of the generation and motion of waves, as connected with the improvements which were to be made in the navigation of tidal rivers. He directed his remarks especially to the tide wave, and to the practical methods which his remarks had led him to, of forming the channel so as to accelerate the tide in its course up the river, but to retard the water as much as possible on its return.

The tidal wave up a river appears to follow laws very similar to the wave of great displacement, of which he had spoken on a previous occasion; hence its progress was to be accelerated by deepening the channel and making its section rectangular. It appeared also, as the result of his investigations, that the wave might be made to move with rapidity in a curve by deepening the channel on the outside of the curve. This deepening the outside of the channel would have the effect of retarding the water flowing back, and thus the tidal water would be preserved for a much longer time than in a straight channel.

Mr. Russell then proceeded to apply the theoretical principles to the explanation of the formation of bores in rivers.

A New Safety Lamp. By W. LEITHEED.

A New Telegraph. By Dr. CLANNY, *Newcastle.*

Telegraphic Communication on Railroads. By BARNARD L. WATSON.

On the Resistance to Railway Trains. By Dr. Lardner*.

The object of this communication was to direct attention to the principles which ought to be preserved in determining railway constants, and especially to the importance of taking into the account the moment of inertion of the wheels, which had been generally omitted. Dr. Lardner detailed generally the various resistances to which the motion of a train is subject; and, having stated his objection to the use of the dyanometer, proceeded to explain the method which he would recommend. The principle is as follows: "Let an engine be loaded with as heavy a train as it is capable of drawing at a very slow and uniform speed, having its steam-valve fully open, and no steam blowing off at the safety-valve. Let care also be taken that the diameter of the steam-pipe, from the boiler to the cylinder, shall bear a considerable ratio to the diameters of the cylinders. Under such circumstances we may, without sensible error, consider the pressure of steam in the boiler and the cylinders to be the same; and if no steam blow off from the safety-valve, the indication of the lever will be a true measure of the pressure of the steam upon the pistons of the cylinders. This pressure is transmitted to the cranks, the mean leverage of which being known, the amount of force transmitted to the point where the driving wheels rest upon the rails is a matter of easy calculation. This will evidently constitute the gross amount of the tractive force exerted by the engine; and this force may be considered as expended in moving the train and the engine, and will be the tractive force sought."†

The important details of this communication will be found in the Railway Magazine as already referred to.

A Flexible Suspension Bridge. By W. J. Curtis.

The peculiar feature of this bridge is the absence of a main chain; each point is sustained by four forces, viz. two bars carried over each pier.

On an Instrument for ascertaining the Focal Length of Spectacles. By John Isaac Hawkins.

Mr. Hawkins mentioned some facts respecting the differences in the distances betwixt the eyes of different individuals, and the focal distance of the right and left eye. In one extreme case this difference was more than 30 inches, the focal distance of one eye being 36, and of the other only 3 inches.

* For an account of this communication and the calculations, see Railway Magazine, November, 1837.

† Ibid.

On the Construction of Sea Walls and Embankments.
By JOHN SCOTT RUSSELL, *F.R.S.E.*

Mr. Russell, from his various researches on the formation of waves, and the methods of increasing or diminishing their velocity, had come to the conclusion that the best form of sea walls and embankments for breaking the waves gradually is a parabolic curve, with the convexity upwards.

On the Duty of the Cornish Engines. By Mr. JOHN TAYLOR, *F.R.S., &c.*

Mr. John Taylor gave some explanation respecting the methods of ascertaining the duty of Cornish engines. He confirmed the statement that one engine had performed 125 millions; but as this experiment only lasted 26 hours, he agreed with Mr. Henwood in considering that much importance was not to be attached to this trial. He considered the method adopted as a perfectly fair one for ascertaining the comparative duties of engines; but it was never asserted that the quantity of water was actually delivered at the adit. The quantity of coals consumed was also another very good test of the duty done, and an examination into the account-books of the different mines confirmed the reports of the duty done.

On Preventing the Dangers from Collision, and from Fire in Vessels.
By Mr. WILLIAMS.

The method now proposed consists in dividing the vessel into several compartments, by division bulk-heads, built up completely through the vessel, similar to the plan which has been adopted in the iron steamers. Thus, should any aperture be made by collision, the water would not extend through the whole vessel, as in the case of the Apollo, but would be confined to the compartment in which the injury takes place. In case of fire, the compartments in which the fire existed might be filled with water without any danger to the rest of the vessel; these bulk-heads would also prevent the existence of any strong current of air throughout the vessel.

Experiments on the Equilibrium of the Arch. By Professor MOSELEY, *King's College, London.*

The results of experiments on the equilibrium of the arch, laid by Professor Moseley before the Section, confirm the theoretical conclusions at which he had already arrived, in papers read before the Cambridge Philosophical Society. In flat arches, the breadth of whose voussoirs are the same, the thrust is found to be as the square of the span, and altogether independent of the depths of the voussoirs. In circular arches, the ratio of the depth of whose voussoirs to their radii

is the same, the thrust is as the square of the radius for the same angle of the semi-arch. The paper was accompanied by diagrams illustrating the manner of experimenting on the arch, and with tables showing the agreements betwixt the theoretical and the practical conclusions.

In connection with his researches on the theory of the arch, the author has instituted experiments to determine the greatest number of voussoirs which could be made to stand in the form of a circular arch.

On the Quality of Iron for Railways. By D. Mushet.

Respecting the qualities most essential for railway iron, Mr. Mushet premises the following remarks:—

1. That a crystalline arrangement of the fracture of bar iron is incompatible with great strength and fibre, and that it is essential to railway iron that it should be hard and fibrous.

2. The more frequently iron is heated or melted in the course of its completion as bar iron, the greater is its tendency to crystallize and become brittle when cold. This is in some measure prevented by repeated rollings; but fibre acquired in this way is, to a certain extent, artificial; for where native fibre is absent, heating and cooling will restore the crystalline arrangement and weaken the tenacity of the iron when cold.

3. Excessive decarbonization, commonly called refining, which tends to deprive the iron of its last portion of carbon, produces a quality of malleable iron, soft, and easily abraded by rubbing or friction; and therefore, in point of durability, not well calculated for rail iron.

4. Conversely, iron manufactured so as to retain the last and consequently the most intimately united portions of carbon, or to have this substance communicated to it in minute portions in working, is better calculated, provided the fibre is not injured, for rail-making on two accounts, because it will wear less by rubbing, and be subject to less waste from oxidation.

5. Bar or malleable iron has a tendency to crystallize in the cooling, in proportion to the size of the manufactured mass; a circumstance deserving the greatest consideration on the part of the engineer in determining the form or shape of his rails.

6. Continued vibration, such as is produced by the motion of an engine or waggon travelling on a railway, causes iron to crystallize and to a certain degree become brittle. Hence the importance of making rails from iron full of fibre, so as to postpone the tendency to crystallization to as remote a time as possible.

7. Unless abridged or destroyed, by the repeated heatings and fusions to which iron is subjected in its various manipulations, the quantity and strength of fibre developed will mainly depend upon the degree or proportion of carbonaceous matter originally contained in the pig iron from which it has been manufactured.

8. It is essential in rail-making to have a quality of iron that will

stand, without dropping or opening at the rolls, a degree of heat capable of compactly and adhesively welding the piles together, so as to prevent exfoliation or a separation of the parts when subjected to railroad traffic.

The qualities most essential for railway iron being fibre and hardness, the attention of the author has been especially directed to the manner of iron having all these qualities in the highest possible degree.

Mr. Mushet considers that the greatest possible quantity of fibre, with a superior degree of hardness and durability, may be produced by avoiding the process and waste of the refinery. The pig iron is to be at once introduced into the puddling furnace, where being subjected to a temperature just sufficient for fusion, some finely-ground rich iron ore is thrown upon it and worked by the puddler into the iron. The usual process of the hammer and the rolls is then gone through.

Several specimens of iron made at different works were exhibited.

On the Teeth of Wheels. By ROBERT WILLIS, *M. A., Jacksonian Professor in the University of Cambridge.*

Two wheels set out by the common plan, with epicycloidal teeth at the same pitch, will work perfectly well; but a third wheel of different diameter, with teeth at the same pitch, will not work with either of them.

To obviate this circumstance, Professor Willis proposes that the teeth should be described on the following principle: If two pitch lines be taken, and a tracing circle of any diameter, and an external epicycloid be traced on the driver, and an internal epicycloid on the driven wheel, the teeth will move each other truly. Professor Willis exhibited also a form of tooth peculiarly applicable to cranes, or wherever the work is only one way and great strength is required.

On the Construction of Vessels with Safety Keels. By Mr. LANG, *of her Majesty's Dock Yard, Woolwich.*

On a New Perspective Drawing Board for Mechanical Drawings. By Mr. KINGSLEY.

On Canals and Railways in America. By Professor HENRY, *Prince Town College.*

Professor Henry gave a most interesting account of the internal communication in the United States, and presented to the Section a map, showing the canals and railways complete or in progress. It appears that 2000 miles of canal and 1800 miles of railway are completed, and that near 3000 miles of railway were in progress; for particular accounts of which he referred to the American Almanac.

On Mechanical Sculpture, with Specimens. By John Isaac Hawkins.

On a New Method of obtaining an Artificial Horizon at Sea. By W. Ettrick.

On the Application of Steam to Long Voyages. By Dr. Lardner.

On the Ventilation of Tunnels. By William West, *of Leeds.*

The writer has found, by experiments repeated under various circumstances in the tunnel on the Leeds and Selby Railway, that even when the external atmosphere is as near to perfect stillness as is common in this climate, an atmospheric current passes through the tunnel with sufficient rapidity to prevent the loss from hot air or gain from cold of more than a very few degrees; and this takes place almost entirely at the entrance, while without rapid transmission it would of course soon reach the mean temperature of the spot.

Sometimes, however, the thermometer shows that the air which enters at the windward end passes up the nearest shaft, leaving the remainder of the tunnel worse ventilated than if no shaft existed. As the results of his experiments, he submits:—

1. That the legislature and the public need apprehend no danger from the stagnation of air in railway tunnels, while they have abundant protection in the enormous cost against any company increasing without occasion either their number or their length.

2. That it is at least doubtful whether open shafts do not rather impede than promote effectual ventilation from end to end.

STATISTICS.

A Brief Memoir of the Growth, Progress, and Extent of the Trade between the United Kingdom and the United States of America, from the beginning of the Eighteenth Century to the present time. By G. R. Porter, *Vice-President of the Statistical Society of London.*

This memoir, after reciting the date of the first settlement of each of the British colonies now included in the confederation forming "The United States of America," contains notices, from the writings of Sir Josiah Child and others, indicating the nature and extent of the commercial intercourse maintained by them with the parent country in the years which immediately followed the dates of their settlement. Tables are given in an appendix to the memoir, wherein the further

progress of that intercourse is more minutely traced, first to the period of the independence of the United States and afterwards to the year 1836. It appears from these data, that so long as the British American provinces continued under the operation of our colonial system, and while their trading was consequently limited to this country, the increase of their imports and exports bore an inedequate proportion to the increased number of the colonists. In 1749, when the population of the provinces was 1,046,000, the value of their imports and exports was £2,117,845. In 1774, when the struggle for independence was begun, the population was estimated at 2,803,625; and if the trade had increased in an equal degree, the amount of imports and exports should have been £5,676,523, instead of the actual amount £3,964,288: thus showing a virtual falling off of 30 per cent. In 1790, when the first census of the United States was taken, the population was 3,929,328, and the amount of trade with England £4,622,851. In 1835, the population was estimated at 14,784,589, and the trade with England amounted to £25,671,602. Comparing this increase of population and trade respectively with the number and amount ascertained at different intermediate periods, the following results are presented.

	Increase per cent. in 1835 of	
	Population.	Trade.
Compared with 1790	276	455
„ 1800	178	177
„ 1810	104	146
„ 1820	53	239
„ 1830	15	57

The growth of the American cotton trade is traced from its beginning in 1787 to the year 1836, in which we received from the United States 218,615,692lbs. of raw cotton, valued at ten millions sterling. Other tables are given, showing the tonnage of shipping employed in the foreign trade of the United States, distinguishing American and British vessels from those under all other flags. These tables are followed by an historical sketch of the progress of the British trade with America, and of the causes and consequences of the interruptions to which it was exposed through the issue of Napoleon's Milan and Berlin decrees, and the retaliatory steps to which those measures led. The memoir closes with a statement of the proportions which the trade between England and the American republic bore to the whole foreign trade of each country respectively in each year, from 1821 to 1835. In the appendix are tables, drawn from our official returns, showing the actual value of British manufactures shipped to the United States in each year, from 1805 to 1836; the quantities of the chief articles of American produce imported, and the quantities and value of the chief articles of British manufacture exported to the United States in each year, from 1827 to 1836; together with parallel statements compiled from returns made to Congress by the American executive government.

On the Wages of Labourers in Manufacturing Districts.
By Mr. SLANEY.

On the State of Education in the Borough of Bolton in 1837.
By Mr. ASHWORTH.

The return made to government in 1833 on the state of education has been found very defective. In Bolton there have been no means of testing its correctness; but, if accurate, there has been a very remarkable increase in the number of scholars, being 25 per cent. more of day scholars and 40 per cent. more of Sunday scholars.

There are now 21 Sunday schools, with 9867 scholars, or $19\frac{3}{4}$ per cent. of the population, of whom about 2000 may be estimated as being in attendance both at daily schools and Sunday schools, leaving the number of 7867, or $15\frac{3}{4}$ per cent. of the population, receiving instruction at Sunday schools only.

There are 66 day and evening schools, containing 3227 scholars, or $\frac{69}{20}$ per cent.

Total number of scholars 11,094, or about $22\frac{1}{5}$ per cent. of the present population, estimated at about 50,000.

Children equal in number to 20 per cent. of the population are not in attendance at any school whatever.

In the Sunday schools were found—

2014 scholars in 4 schools connected with the Church Establishment.

1085 scholars in 1 Roman Catholic school.

6768 scholars in 16 schools belonging to various classes of Dissenters.

In Bolton there are 5 charity schools, with 692 scholars, including the two infant schools. There is also a grammar school, whose scholars have been entered at 120, being the number reported to government, the master having declined to give the agent any information on the subject. The income was stated to the committee to be £450.

Of superior schools for the children of persons in good circumstances there appear to be 17, with 721 scholars.

Of common boys' schools there are	15, with	851 scholars.
Of common girls' schools........	5,	209
Of Dame schools..............	23,	634

—944 being boys and 750 girls, all the boys' schools containing some girls, and *vice versâ*.

Remarks on the Report of the State of Education in Liverpool, presented to the British Association in 1836. *By Mr.* MERRITT.

The author dissenting from the numerical results stated in the report alluded to (of which an abstract is given in the preceding volume, p. 133.), assigned his reasons for this difference of opinion.

Mr. Tate also presented remarks on the same subject.

On the State of Crime in the Borough of Liverpool. By Mr. WALMSLEY.

The author presented returns relating to Liverpool, containing the number of persons brought before the magistrates, and the number committed; the number of felons apprehended, and the number committed; and the ages of the juvenile felons. In the year 1835, 13,506 were taken into custody, 2138 of whom were committed. In 1836, 16,830 were taken into custody, of whom 3343 were committed. Up to the 13th of September, 1837 (eight months), the number taken into custody was 12,709, of whom 2849 were committed. From July 1835 to July 1836, the number of juvenile thieves apprehended under eighteen years of age, was 924, of whom 378 were committed. From July 1836 to 13th of September 1837, the number of juvenile thieves apprehended was 2339, of whom 1096 were committed. There were in custody, during the same period, upwards of 1500 well-known adult thieves.

Abstract of the Report made by the Regents of the University of the State of New York. By Dr. W. C. TAYLOR.

On Improvements in Agriculture. By G. W. HALL.

On Spade Husbandry. By Dr. YELLOLY.

On the Localities of the Plague in Constantinople. By Mr. URQUHART.

The author stated, as the result of three years' observations, that the plague, if it did not originate in localities close to cemetries, was greatly aggravated by the proximity of burial grounds, especially when the towns and villages stood on a lower level than the neighbouring cemetries. Several statements corroborative of this view of the injurious effects of effluvia from the shallow Turkish graves, were advanced by other members of the section.

On the Reclaiming of the Bog of Critt, in the County of Galway. By Mr. BERMINGHAM.

On the Condition of the Poor of Bristol—an Inquiry now carrying on by the Statistical Society of Bristol. By C. B. FRIPP.

The inquiry, though much advanced, being still in progress, it appears proper to defer an abstract of the results obtained till the whole is completed.

On the Educational Statistics of the Parish of Sidlesham, in Kent. By the Rev. F. De Soyres. *Communicated by* C. B. Fripp.

Population by census of 1831			1002.
in 1837			1100.
Schools, in number 6, of which,	Day schools,	3,	with 93 scholars.
	Dame schools,	1,	15
	Sunday do.,	2,	123
40 Sunday scholars also attend day-schools.			231

Adult Population.	Agricultural class.		
Able to read	males	55 married;	28 unmarried.
	females	83	27
Not able to read	males	42 married;	22 unmarried.
	females	30	1
	Miscellaneous class.		
Able to read	males	38 married;	16 unmarried.
	females	40	9
Not able to read	males	6 married;	3 unmarried.
	females	6	2

An Inquiry into the Origin, Procedure, and Results of the Strike of the Operative Cotton-Spinners of Preston, from October 1836 *to February* 1837. *By Mr.* Ashworth, *of Bolton.*

In October 1836, there were in Preston and its vicinity, 42 cotton-mills, giving employment to 8500 hands, and requiring about 1200 horse power to work them. The capital invested in the buildings, machinery, &c. was about £550,000

The working capital, about 250,000

Total. . £800,000

In consequence of a struggle between the operatives and the masters, concerning the rate of wages, which the masters proposed to advance 10 per cent., the operatives ceased working on the 5th of November, when 660 spinners, 1320 piecers (children employed by the spinners), 6100 card-room hands, reelers, and power-loom weavers, 420 overlookers, packers, engineers, &c., making in all 8500 persons, were without employment. Weekly payments were made to them from the funds of the "Trades' Union" previously established, but the distress became great, and in December, notwithstanding the grant of £100 from the corporation, "universal and intense." The mills were re-opened by the masters, to such as chose to work, on the 9th of January, and the scale of prices was fixed as previously offered by the masters, viz. an advance of 10 per cent. By degrees, almost all the work-people resumed their employments, and on the 5th of February the mills were in full operation.

The following estimate was made of the direct pecuniary loss to all classes of operatives in consequence of the turn-out.

Wages of 660 spinners for 13 weeks	22*s*. 6*d*.	=	£9,652
of 1320 piecers	5*s*. 6*d*.	=	4,719
of 6520 card-room hands, &c.	9*s*.	=	38,142
8500			
Estimated loss sustained by hand-loom weavers in consequence of the turn-out			9,500
Estimated loss sustained by clerks, waggoners, carters, mechanics, dressers, sizers, &c.			8,000
Total......			70,013
From which must be deducted			
Estimated amount of wages earned between 9th of January and 5th of February			5,013
Estimated value of relief given by masters			1,040
Other private charity and parochial relief			2,500
Allowance to spinners and piecers from the funds of the union			4,290
			12,803
Leaving a nett pecuniary loss to the whole body of Preston operatives of			57,210
Loss to the masters (three months' interest on £800,000)			45,000
Loss to shopkeepers			4,986
Total loss to the town and trade of Preston			£107,196

Report of a Committee of the Manchester Statistical Society, on the condition of the Working Classes in an extensive Manufacturing District, in 1834, 1835, and 1836.

This inquiry embraced,

Manchester, with a population of about	200,000
Salford, ...	55,000
Bury, ...	20,000
Ashton, ...	22,000
Stalybridge, ...	17,200
Dukinfield, ...	8,600
	322,800

The information was obtained by agents employed to visit every dwelling, and was by them recorded in the manner exemplified in the annexed form.

The information thus collected was classified in a series of tables, which were accompanied by an explanatory report.

The whole has since been published for the Manchester Statistical Society, by Messrs. James Ridgway and Son.

House or Cellar.		H	...	...	...
Number of Persons in the House or Cellar.		17	...	...	...
Number of Rooms in the House or Cellar.		8	...	...	...
Number of Families in the House or Cellar.		4	...	...	...
Name.		J.G.	T.S.	O.T.	N.G.
Number of Adults.	Male.	2	...	1	1
	Female.	1	1	...	3
Number of Children.	Male.	3	1	...	1
	Female.	1	1	...	1
Religious Profession of the Head of each Family.	Church of England.	7	3	...	...
	Protestant Dissenters.	...	...	...	...
	Roman Catholics.	...	...	...	...
Country of the Head of each Family.	English.	7	3	...	...
	Irish.	...	...	1	6
	Scotch.	...	...	...	...
	Welsh.	...	...	...	...
	Foreigners.	...	...	...	...
Occupation or Trade of the Head of each Family.		Carpenter.	...	Bricklayer.	Labourer.
Occupation or Trade of any other Members of the Family.		Carpenter.	...	...	...
Number of Adults in the Family earning Wages.		2	...	1	1
Number of Children in the Family earning Wages.		...	...	...	...
Number of Children attending a Day School.	Male.	2	1	...	...
	Female.	1	...	...	...
Number of Children attending a Sunday School.	Male.	2	...	...	1
	Female.	1	...	...	2
Total weekly Payment for Schooling of Children.		2s.	6d.	...	...
Are there any Books in the House?		Yes.	Yes.	No.	No.
Dwelling comfortable.		Yes.	Yes.	Yes.	Yes.
Dwelling well furnished.		Yes.	Yes.	No.	No.
Weekly Rent.		3s. 0d.	2s. 0d.	1s. 6d.	2s. 0d.
Number of Rooms for the Family.		3	2	1	2
Number of Sleeping Rooms for the Family.		2	1	1	1
Number of Beds for the Family.		3	2	1	2
Sufficient supply of Water.		Yes.	Yes.	Yes.	Yes.
How long has the Family been resident in the Town?		5 years.	native.	4 years.	3 years.
Does the Head of the family belong to any Benefit Society.		Yes.	No.	No.	No.
Name of Street.		Clarence Street.			

Account of the Inhabited Courts and Cellars in Liverpool, &c.

Whilst conducting the inquiry into the state of Education in Liverpool, in 1835–6, the agent of the Manchester Statistical Society took an account of the number of inhabited courts, and of the cellars occupied as dwellings in that borough, of which the following is the summary :—

	Courts.	Cellars.
Parish of Liverpool	1964	6506
Portions of four other townships, included within the limits of the borough	307	987
Total in the borough of Liverpool ...	2271 ...	7493*

Estimated population of the borough .... 230,000.

No courts were counted, in which two or more families did not reside, and above one-third of the whole number contained six or more families. Few of the courts had more than one outlet.

No cellars were included in the above number in which the occupants did not sleep, as well as live by day; nor was any account taken of those occupied as gin-shops. The great proportion of the inhabited cellars were dark, damp, confined, ill-ventilated, and dirty.

From the evidence afforded by this inquiry, it appears that, taking an average of five to each cellar, there must be about 15 per cent. of the entire population of Liverpool occupying cellar residences; but alowing 4·17 to each cellar, (the average in Manchester and Salford,) there would be 31,000 persons inhabiting cellars in Liverpool, out of a total population of 230,000; or, taking the working population at two-thirds of the whole, about 20 per cent. of that portion of the community.

In York no inhabited cellars were found.

The proportion of the working population residing in cellars was found to be,

In the borough of Manchester	$11\frac{3}{4}$	per cent.
In the borough of Salford	8	„
In Bury	$3\frac{3}{4}$	„
In Ashton	$1\frac{1}{4}$	„
In Stalybridge.................................	$1\frac{1}{2}$	„
In Dukinfield	$1\frac{3}{4}$	„

* This report having caused much surprise, an examination was immediately instituted; and, on the following day, Mr. Adam Hodgson presented to the Section the following return, made by the inspectors to Mr. M. J. Whitty, head constable :—

North Division	4,004	Inhabited Cellars.
South ditto	3,858	ditto.
Total	7,862	

The excess of 369 cellars, in Mr. Hodgson's return, is accounted for by the extension of building since the date of the first inquiry. In Toxteth, a very rapidly increasing district of the borough, a cellar dwelling is attached to almost every new house in the streets inhabited by the working classes.

Inquiry into the State of Education in the City of York. By the Manchester Statistical Society.

This inquiry was carried on in 1836 under the direction of Mr. W. R. Greg, Mr. W. Langton, and Mr. H. Romilly, and the report showed the followed results:—

The number found in attendance at the different schools in the city was 5591, of whom

2228 or 7·96 per cent. of the population attended day and evening schools *only*.
2521 or 9 per cent. of the population attended *both* day and Sunday schools.
4749 or 16·96 per cent. of the population.
842 or 3·01 per cent. of the population attended Sunday schools *only*.
5591 or 19·97 per cent. of the population.

The population of the city is taken at 28,000 in this calculation, which shows that nearly one-fifth of the population is in attendance at schools.

It is assumed that the number of children in the city between the ages of 5 and 15 years is about 7000, and the general summary shows that only about 4700 of the children between 5 and 15 can have been in attendance at school at the date of the inquiry; thus above 33 out of every 100 must be absent from school. This approaches very closely to the result shown in the examination of Manchester and Salford. In the manufacturing districts, however, above half of the total number of scholars were found to attend *only* a Sunday school; while in York the proportion attending Sunday schools only is 15 per cent.

Several errors appear to have occurred in the returns made to the Government in 1833, so that it could not be exactly ascertained what increase or otherwise had taken place since that time.

An account of the state of education in York was collected in 1826 by a Committee of the Society of Friends, a copy of which accompanies this report; but as its principle of classification is different, it shows no result which allows of a close comparison with the present report.

The tables annexed to the report classified in figures are the most important features of the state of education in the city of York. Some of these are annexed.

In the following tables York is compared with other towns examined by the Manchester Statistical Society.

SUPPLEMENTARY TABLE.—I.

ESTIMATED POPULATION.	200,000.	55,000.	20,000.	230,000.	28,000.
PER CENTAGE OF THE POPULATION WHO	Manchester.	Salford.	Bury.	Liverpool.	York.
Attend Dame Schools	2·36	2·81	4·20	2·28	2·66
Common Day	3·40	3·30	4·04	2·65	1·96
Superior Private	1·47	1·60	·87	1·77	2·56
Infant....................	·32	·68	1·42	·96	1·48
Evening..................	·73	·96	·75	·24	·15
Endowed and Charity	1·78	2·55	1·84	4·91	8·15
Total who atttend Day Schools	10·06	11·90	13·12	12·81	16·96
.... Sunday ... *only*	11·59	11·53	15·51	1·62	3·01
Total who attend any Schools	21·65	23·43	28·63	14·43	19·97

SUPPLEMENTARY TABLE.—II.

PER CENTAGE OF THE TOTAL NO. OF SCHOLARS WHO	Manchester.	Salford.	Bury.	Liverpool.	York.
Attend Dame Schools	10·90	11·97	14·67	15·79	13·33
Common Day	15·68	14·08	14·11	18·37	9·82
Superior Private	6·77	6·85	3·03	12·30	12·80
Infant....................	1·50	2·89	4·96	6·64	7·44
Evening..................	3·37	4·08	2·64	1·65	·75
Endowed and Charity	8·24	10·89	6·43	34·04	40·80
Total who attend Day Schools	46·46	50·76	45·84	88·79	84·94
Ditto .... Sunday ... *only*	53·54	49·24	54·16	11·21	15·06
Grand Total.........	100·	100·	100·	100·	100·

GENERAL SUMMARY OF SCHOOLS AND SCHOLARS IN THE CITY OF YORK, IN 1836.

POPULATION IN 1831, 25,359.		SCHOLARS.						PER CENTAGE.		
		AGE.			SEX.					
DESCRIPTION OF SCHOOLS.	Schools.	Under 5.	Between 5 and 15.	Above 15.	Male.	Female.	TOTAL.	Of the total population estimated at 28,000.	Of the whole No. of Scholars	Of the whole No. of Sunday Scholars.
SUNDAY SCHOOLS.										
Church of England	15	49	1606	53	858	850	1708	6·10	30·55	50·79
Dissenters	9	124	1505	26	864	791	1655	5·91	29·60	49·21
Total	24	173	3111	79	1722	1641	3363	12·01	60·15	100·00
		5·14 p.c.	92·51 p.c.	2·35 p.c.	51·21 p.c.	48·79 p.c.				Per centage of the whole No. of Day Scholars.
Returned also as Day or Evening scholars	...	...	...	...	...	...	2521	9·00	45·09	
Receiving Sunday-school tuition only	...	...	...	...	...	...	842	3·01	15·06	
DAY SCHOOLS.										
Dame Schools	37	287	458	...	270	475	745	2·66	13·33	15·83
Common Boys' and Girls' Schools	23	75	471	3	300	249	549	1·96	9·82	11·66
Superior Private and Boarding Schools	30	45	615	56	264	452	716	2·56	12·80	15·21
Supported solely by the Scholars	90	407	1544	59	834	1176	2010	7·18	35·95	42·70
Infant Schools assisted by the Public	3	172	244	...	205	211	416	1·48	7·44	8·84
Other Charity Schools, Endowed Schools, and Schools attached to Public Institutions, or conducted by Committees.—*Vide List*	31	28	2187	66	1155	1126	2281	8·15	40·80	48·46
Total	124	607	3975	125	2194	2513	4707	16·81	84·19	100·00
		12·89 p.c.	84·45 p.c.	2·66 p.c.	46·61 p.c.	53·39 p.c.				
EVENING SCHOOLS.										
Supported by the Scholars	2	...	6	36	23	19	42	0·15	0·75	
			14·29 p.c.	85·71 p.c.	54·76 p.c.	45·24 p.c.				
TOTAL No. OF SCHOOLS AND SCHOLARS	150	...	...	...	...	...	5591	19·97	100·00	
Evening School attached to Sunday-Sch.	1	...	21	...	16	5	21	...	...	
Average attendance at Sunday Schools	...	...	...	...	...	...	2271	...	...	
							67 p. c.	...	...	

ABSTRACTS OF THE RETURNS FROM THE DIFFERENT PARISHES OF YORK.

MADE BY A COMMITTEE OF THE FRIENDS OF EDUCATION, 27TH JANUARY, 1836.

PARISHES.	No. of Children under 14 years of age at home	No. from 2 to 6 years of age at home.	NO. FROM 6 to 10 YEARS OF AGE. Go to Day-school.		Go to no Day-school.		NO. FROM 10 TO 12 YEARS OF AGE. Go to Day-school.		Go to no Day-school.		NO. FROM 12 TO 14 YEARS OF AGE. Who can read.		Who cannot read		Go to a Sun-day-school, and not to a Day-School.		POPULATION IN 1821.		
			Boys.	Girls.	Boys.	Girls.	Boys.	Girls.	Boys.	Girls.	Boys.	Girls.	Boys.	Girls.	Boys.	Girls.	Males.	Females	Total.
St. Saviour's and St. Andrew's	272	120	38	18	11	12	21	10	5	4	11	1	...	...	1	2	528	644	1172
St. Mary's, Bishop Hill, Senior	207	69	23	24	4	9	8	14	3	11	6	10	1	...	5	7	297	384	681
St. Mary's, Bishop Hill, Junior	212	84	16	31	2	3	19	8	1	1	8	5	1	1	1	8	340	427	767
St. Martin's, Micklegate	48	21	3	10	...	2	3	2	...	1	3	2	...	...	...	3	245	317	562
St. Cuthbert's, St. Helen's on the Walls, and All Saints	247	96	43	46	9	6	14	20	4	9	...	...	...	...	...	...	389	441	830
St. John's, Micklegate	198	63	22	25	13	6	11	8	8	...	10	12	...	...	6	2	432	506	938
St. Michael's Belfry, St. Wilfred's, & Mint Yard.	275	135	50	33	4	4	15	6	2	4	4	10	...	...	2	1	774	928	1702
All Saint's, North-street	260	105	43	35	8	10	7	12	1	5	3	5	...	...	4	8	446	464	910
St. Laurence and St. Nicholas	129	33	13	12	9	8	5	4	4	3	5	7	1	1	6	9	367	432	799
St. Maurice and St. John, Delpike	121	68	13	15	4	1	4	5	4	2	...	...	2	2	2	2	525	640	1165
Trinity, Micklegate	168	62	28	10	9	9	8	4	2	3	4	3	1	1	3	16	341	504	845
St. Mary, Castlegate	164	62	20	13	3	10	7	6	4	2	6	10	...	1	9	5	468	521	989
St. Michael, Spurriergate	127	35	19	14	7	4	14	8	3	3	8	5	2	2	1	5	288	305	593
St. Dennis and St. George, Walmgate	284	126	26	30	11	15	9	7	9	8	10	13	1	...	9	11	505	588	1093
St. Peter the Little, and All Saint's, Pavement.	155	71	23	17	6	7	8	8	3	4	3	3	...	1	4	4	599	615	1214
St. Margaret and St. Peter, the Willows	243	119	21	13	17	16	5	2	8	5	12	4	3	2	3	1	591	635	1226
Christ Church, Haymarket	87	42	13	14	2	4	3	2	1	2	3	1	...	...	2	1	353	384	737
Bedern and Minster Yard	181	53	32	25	9	9	12	10	5	7	2	3	1	2	3	10	407	517	924
St. Olave, Mary Gate, and St. Giles	366	121	47	33	4	9	20	21	6	7	37	10	...	1	7	6	672	875	1547
Trinity, Goodramgate	68	29	4	1	4	5	1	2	2	1	4	1	1	1	...	...	238	289	527
St. Helen's, Stonegate	42	26	5	3	2	2	2	1	...	...	...	1	...	...	...	4	291	387	678
St. Martin's, Coney-street	20	9	1	8	2	4	...	1	...	...	...	...	...	...	...	...	228	382	610
St. Sampson	205	108	15	23	8	7	10	10	3	12	1	1	1	2	1	4	496	545	1041
St. Crux	100	41	16	6	3	6	5	4	4	2	6	3	4	...	4	6	419	408	827
Total	4179	1698	534	459	151	168	211	175	82	96	146	110	19	17	73	115	10239	12138	22377

By these Returns, it appears that, of the Children between the ages of Six and Ten, nearly one-fourth do not go to any Day-school; that between the ages of Ten and Twelve, nearly one-third do not go to any Day-school; that between the ages of Twelve and Fourteen, upwards of one-ninth part cannot read; and that of the Children who do not go to Day-schools, two-fifths go to Sunday-schools.

Abstract of a paper entitled "Remarks upon the Importance of an Enquiry into the Amount and Appropriation of Wages by the Working Classes." By WILLIAM FELKIN, *Nottingham.*

The preliminary observations contain the writer's idea of the large amount of many skilful workmen's wages, and their misappropriation. He considers his views of their want of providential care for themselves and their families corroborated by circumstances which occurred in Nottingham during the spring of 1837, which he proceeds to relate.

The general commercial pressure bore so heavily upon Nottingham as to throw a large portion of the working people out of employ; and in April, much suffering being apparent, the unemployed in the hosiery and lace trades of the neighbourhood, not paupers, were set to work in the construction of a new road, by a committee appointed to distribute £5000 raised by public subscription for the purpose: £4322. 19*s*. 6*d*. of this sum was expended in this way in 18 weeks; the remainder was paid for tools (reserved) and other necessary expenses. On the 19th June there were at work 49 single men; 76 men married, without children; 182 having one child; 224 with two; 179 with three; 135 with four; 80 with five; and 65 with six or more children; making a total of 990 men, having 941 wives, and 2576 children under 16 years of age; 4407 were dependent that day on the fund, which was the largest number that occurred. The road has been since completed, leading to 100 garden allotments which have been made to the poor of land before useless. The total number of applicants were, lace-makers 839, stockingers 797, smiths 178, sundries 164, total 1978 men, having 1401 wives and 3508 children; being 6887 persons destitute. 889 belonged to Nottingham, 1024 to the county, 65 elsewhere: 1083 lived in Nottingham, 591 in the Radford Union, 304 in the parishes around. Being soon overpowered by the numbers of applicants, the Committee caused rigid inquiries to be made into the circumstances and character of each new one. Out of 1100 returns, 1043 are perfect, comprising 452 stockingers and 498 lace-makers, and 93 smiths dependent on the other two trades. Their wives and children were almost entirely unemployed. Character, as "clean," "comfortable," "industrious," "sober," "steady," "very poor," "very destitute," "honest," or the reverse, was given. 440 lace-makers have good and 39 bad characters; 360 stocking-makers good, 50 the reverse; 75 smiths favourable, 13 not so; total, 875 good, and 102 indifferent characters. On the whole, they were decent work-people.

Eight only had been pauperised in any form.

The length of time the stocking-makers had been partly unemployed was an average of 17 weeks, 1½ days; lace, 21 weeks, and half a day; smiths, 20 weeks, 1¼ days; total average of partial employ, 19 weeks, 3 days. Totally unemployed, stocking makers, 5 weeks, 1 day; lace, 8 weeks, one day; smiths, 8 weeks, 2 days; total average of entire want of employ, 6 weeks, 5 days. *Not one of the* 1043 *stated himself to be a depositor in the Savings' Bank.* 104 stocking-makers were in sick clubs, odd fellows' societies, &c.; 141 lace and 18 smiths, total 263

or one in four persons had provided for scarcely any thing more than future sickness. The higher or lower rate of wages does not seem to influence materially the desire to belong to these clubs, or to lay by for future contingencies. 210 stocking-makers earned 11*s.* a week and under, of whom 43 were in sick clubs; 103 earned 12*s.*, of whom 22 were in sick clubs; 139 earned 13*s.* and upwards, of whom 39 were in sick clubs. Total average of stocking-makers' earnings, 11*s.* 6$\frac{3}{4}$*d.* a week: 176 of their wives averaged 1*s.* 10$\frac{3}{4}$*d.* 212 lace earned 14*s.* and under, of whom 41 were in clubs; 72 earned 15*s.*, of whom 21; 69 earned 16*s.*, of whom 27; 143 earned 17*s.* and above, of whom 52 were in sick clubs. Average lace earnings, 15*s.* 1*d.*; and of 182 wives, 2*s.* 1$\frac{1}{4}$*d.* 93 smiths averaged 16*s.* 4*d.*, and 34 wives 1*s.* 9*d.* a week. Total average earnings of 1043 men weekly, 13*s.* 7$\frac{1}{4}$*d.*; 392 wives 1*s.* 11$\frac{1}{2}$*d.* a week: and of each family when in full work, according to their own statement, 17*s.* 6*d.* Though the inquiry has been a difficult one, yet this amount is found to be somewhat considerably below the actual weekly sum received. 304 of the men had an average of 2 children each able to work, bringing in together 3*s.* a week. 661 had 300 children between 11 and 7 years of age, and 1300 below 7, or 2$\frac{1}{2}$ on an average.

The wages of Nottinghamshire lace hands averaged, in 1829, 25*s.*, 1831, 20*s.*, 1833, 19*s.*, in 1836, 17*s.* a week, rates established by the writer's statistical paper of those years. Those employed on this fund stated their earnings at 15*s.* Stocking-makers' wages had risen from 9*s.* in 1833, to 11*s.* 6*d.* in 1836. Neither the past difficulties of the last class, nor the prospective depression of the first, seems to have taught them economy. These papers however show the fact, that men with 5 or 6 children have supported themselves as long as the unmarried, and form the bulk of the contributors to sick clubs, &c. The average weekly pay from the fund was 8*s.* 7$\frac{3}{4}$*d.* a man, or 1*s.* 10*d.* a week for each person dependent upon it; yet notwithstanding the smallness of this sum, and the whole of the people being unaccustomed to this kind of employment, they soon began to assume a far more healthy and cheerful aspect in person and countenance, than when engaged in their ordinary pursuits; and many stated themselves stronger and better than formerly. Hay harvest coming on, and the numbers (which had been greatly reduced) having drained the resources of the Committee, the affair was terminated; having been so managed as on the whole to give general satisfaction.

From these facts the following conclusions are drawn.

That the number of distressed applicants from one of the highest paid trades, the lace, was as large as from one of the lowest, the stocking-makers; the one having fallen in a few years from upwards of 40*s.* to under 20*s.*, the other having risen from 7*s.* to about 12*s.* a week; the numbers employed in each trade in the district in question being nearly equal. The higher paid trade had afforded its workmen means of effecting considerable savings; but the number who made provision for the future in sick clubs, &c., did not rise with the larger amount of wages; for of the 245 members, 132 were of those who had

earned 14*s.* a week and under, (the average wages being 13*s.* 7*d.*,) and 113 were of those receiving above that sum. The kind of provision was partial, not meeting trade fluctuations at all; and unsatisfactory, because sick clubs are often ill managed, insolvent, and held at public houses: the Savings' Bank was neglected, which is secure, and gives facilities for receiving and withdrawing deposits to suit every emergency. These 1043 cases, being unselected ones, and the returns impartially dealt with, give results similar to those obtained from inquiries and observations carried on in other manufacturing districts, and indicate an important defect in the economic principles and conduct of the well-paid amongst the manufacturing workmen; and seem to justify the writer in urging upon this Section and statistical societies, an inquiry into the best mode of ascertaining upon a large scale the rates and appropriation of earnings. After the preceding statements were drawn up, the writer made out a classified account of the depositors in the Nottingham Savings' Bank. This document confirms the views he has stated; for the number and amount of deposits from the work*men* in the staple trades is very small, but large from the work*women*, whose wages are invariably of but moderate amount. By far the largest part of the sum deposited is by domestic servants; their number was 1813; dress makers, cheveners, widows, governesses, &c., 924; labourers 702; artisans 443; clerks 77; retail traders 497; lacemakers 437; stockingers 360; trustees 509; sundries, chiefly infants, 339; total 6101; in 1836, 6218; accounts decreased during this pressure in trade 117. The balances of 6057 accounts amounted to £142,328, or £23. 10*s.* each; 267 lace deposits amounted to 14*s.* 4*d.*, and the other 170 to £28 each; 120 stockingers' deposits to £1 each, and the remaining 240 to £23. 18*s.* each. The smaller sums are evidently mere balances. The real depositors in the staple trades are 410, and amount to £10,495. These have been scarcely affected by the late pressure, either in number or amount.

P. S. It may be proper to state that, the Section having requested the publication of this paper, the writer urged upon the well-paid working classes the duty and benefit of exercising economy and foresight in the disbursement of their wages, through a few pages of supplementary observations; and four editions of about 10,000 copies have been distributed (three of the editions at the expense of private individuals,) chiefly amongst the working people of the manufacturing districts.

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Anderson, Joseph, M.D., 5, Oxford St., Liverpool.
Anderson, James, F.R.S.E., Edinburgh.
Anderson, David, of Exeter Coll. Oxon., Edinburgh.
Anderton, Henry, Woolton, near Liverpool.
Andrade, Joachim, 68, Duke St., Liverpool.
Andrew, H. P., Bodrean, Truro.
Ansted, D. T., Jesus College, Cambridge.
Appleton, Rev. Richard, A.M., 22, Springfield, Liverpool.
Archbold, James, Newcastle.
Archer, Francis, Renshaw Street, Liverpool.
Ariel, Miles, Bristol.
Armstrong, G. A., Dublin.
Armstrong, W. J., Rathcoale, Co. Dublin.
Armstrong, William, Bristol.
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Ash, Richard, Bristol.
Ash, R. H., Middle Temple.
Ash, J. H., Bristol.
Ashburner, George, London.
Ashton, H., Woolton Wood, Liverpool.
Ashton, C. E., Woolton Hall, Liverpool.
Ashton, H. P., Gildart St., Liverpool.
Ashton, Jos. Yates, South John Street, Liverpool.
Ashton, Michael, 2, Gildart St., Liverpool.
Ashworth, Thomas, Poynton, Stockport.
Ashworth, Samuel, Oxford.
Aspinall, Rev. James, Abercromby Sq., Liverpool.
Aspland, A. S., Temple.
Aston, Lieut. Henry, of Bombay Army, Torquay.
Atcherly, John, 3, Gt. George's Place, Liverpool.
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Avison, Thomas, Jun., Catherine Street, Liverpool.
Austen, Robert A. C., Stratford House, Guildford.

B.

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Backhouse, William, Newcastle.
Backhouse, T. I., Sunderland.
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Badham, J. B., Bristol.
Baen, Martin, Bristol.
Bailey, Lieut. Joseph, R.N., Bristol.
Bailie, Rev. Dr. Kennedy, ArdtreaHouse, Tyrone.
Baily, Fran., Treas. R.S., F.G.S., London.
Baily, James, Brighton.
Baines, Thomas, Hope St., Liverpool.
Baird, David, M.D., 97, Duke Street, Liverpool.
Baker, Thomas, Bristol.
Baker, George, Northampton.
Baker, T. B. L., Hardwick Court, Gloucester.
Balcarras, The Earl of, Haigh Hall, Wigan.
Bald, William, F.R.S.E., Board of Works, Dublin.
Ball, Rev. John, Manchester.
Ball, John, Seacombe, Cheshire.
Ball, Nicholas, 85, Stephen's Green So., Dublin.
Balleny, William, 50, Oxford Street, Liverpool.
Bangley, George, 24, St. John's Wood Road.
Banner, J. M., 24, Rodney St., Liverpool.
Banning, T. H., 27, CanningSt., Liverpool.
Barber, Thos., Exchange Alley North, Liverpool.
Barber, Charles, 18, Moira St., Liverpool.
Barclay, Thomas, Castlebar.
Barclay, T. B., Wavertree Lodge, Liverpool.
Bardon, Rowland, HamptonHall, Ireland.
Bardsley, S. A., M.D., Manchester.
Bardsley, J. L., Manchester.
Barham, Dr. T. F., Exeter.
Barham, Francis, London.
Barker, Rev. Frederick, B.A., Edge Hill, Liverpool.
Barker, James, 24, North Cumberland Street, Dublin.
Barker, Rev. T. F., Everton, Liverpool.
Barker, James, Bakewell, Derbyshire.
Barker, Rev. Henry, Clifton.
Barnard, W. H., South Shields.
Barratt, John, Conistone, near Kendall.
Barrow, Samuel, Bath.
Barton, Stephen, Bristol.
Batchelor, W. M., Abbeville, County Dublin.
Bates, John, Clifton.
Bath and Wells, The Lord Bishop of, Palace, Wells.

Bathurst, Earl, Cirencester.
Batty, C., Liverpool.
Baumgartner, A., Manchester.
Bayly, John, Abbott's Leigh, Bristol.
Bayly, T. K., Abbott's Leigh, Bristol.
Bayne, Rev. Thomas, Warrington.
Baynton, William, Bristol.
Bealey, Richard, Radcliffe.
Beardman, Joseph, Chesterfield.
Beasley, Thos., Fitzwilliam Sq., Dublin.
Beatty, T. E., M.D., M.R.I.A., 16, Molesworth Street, Dublin.
Beaufort, His Grace the Duke of, Badminton.
Beddoes, Lieut. C. H., R.N., Clifton.
Bedford, R. G., Clifton.
Beilby, William, M.D., Edinburgh.
Bell, David, Blessington Street, Dublin.
Bell, T. B., Edinburgh.
Bell, J. W., Q.C., 1, Gardiner Street, Dublin.
Bell, Peter, M.D., Wolverhampton.
Bell, John, Royal Barracks, Dublin.
Bell, Matthew, M.P., Wolsington, Newcastle.
Bellamy, Wm., Rodney Street, Liverpool.
Bellingham, Rev. J. G., B.A.
Beney, Perceval, Bedford Row.
Bennett, Richard, Bristol.
Bennett, C. F., Clifton.
Bennett, Henry, Bristol.
Bennett, G., St. John's, Newfoundland.
Benson, Rob., Jun., Lodge Lane, Liverpool.
Benson, W. W., Lieut. 57th. Regiment.
Benwell, Rev. William, Stanton Drew.
Berend, S. S., Bold Street, Liverpool.
Bernard, C. E., M.D., Clifton.
Berkeley, F. H., St. John's Priory, Chester.
Bernard, F. J., Bristol.
Bernard, R. M., Bristol.
Bernard, R. W., M.D., Cheltenham.
Bernard, W. H., Whitburn, Durham.
Bernard, W. R., M.A., Clifton.
Berry, Rev. William, Settle, York.
Bessonet, James, 28, Leeson St., Dublin.
Bettune, William, Boston.
Bevan, John, Great George Square, Liverpool.
Bevan, John, Cowbridge, Glamorgan.
Bevan, Samuel, Neath.
Bevan, William, 3, Leeson St., Dublin.
Bevan, Rev. William, Frazer Street, Liverpool.
Bevan, Robert, M.D., Monmouth.
Biggs, Arthur, Bristol.
Bickford, J. S., Hayle, Cornwall.
Biddle, John, Leamington.
Biddle, James, 16, Mount Pleasant, Liverpool.
Bigg, L. O., Bristol.
Bigge, Chas. J., Dunston Hill, Durham.
Bigge, C. W., Linden, Newcastle.
Biggs, R. H., Bristol.
Biggs, William, Leicester.
Biggs, John, Leicester.
Billett, James, Taunton.
Bincks, C., Edinburgh.
Birch, Sir T. B., Bart., Prescot.
Bird, Golding, Guy's Hospital.
Bird, William, Dingle Mount, Liverpool.
Birkbeck, William, Settle, Yorks.
Birrell, Rev. C. M., Roscommon Street, Liverpool.
Bishop, C. K., Tiverton.
Black, James, M.D., Bolton.
Black, William, 65, Cornhill.
Blackaller, Rev. H., Clapville, America.
Blackburn, E. B., Alnwick Castle.
Blackburn, James, Alnwick Castle.
Blackburn, J. J., M.P., Warrington.
Blackburn, T., Camden St., Liverpool.
Blackett, Christopher, M.P., Wyham Oakwood, Newcastle.
Blackhall, Rev. Samuel, North Cadbury.
Blain, William, Mount Vernon, Liverpool.
Blair, Harrison, Mill Hill House, Bolton.
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Blake, Jas., Jun., Great George Square, Liverpool.
Blake, William, Crewkerne.
Bliss, Thomas, Jun., Trin. Coll., Dublin.
Blisset, Charles, Clifton.
Blood, W. Bindon, Edinburgh.
Blower, Benjamin, Surgeon, Northern Hospital, Liverpool.
Blundell, William, Crosby Hall, Liverpool.
Blundell, Richard, Hooton, Cheshire.
Boisragon, Theodore, Cheltenham.
Bold, N. D., Duke St., Liverpool.
Bold, Rev. Thomas, Duke Street, Liverpool.
Bold, Thomas, Water Street, Liverpool.
Boley, Richard, Ashley Hill, near Bristol.
Bolton, Ogden, Great George's Street, Liverpool.
Bompas, G. G., M.D., Fishponds, near Bristol.
Bompas, G. J., Jun., Fishponds, Bristol.
Bompas, C. C., 11, Park Road, Regent's Park.
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Booker, Josias, Allerton, Liverpool.
Booth, Abraham, Hackney.
Booth, Charles, Bedford Street North, Liverpool.

Booth, John, M.D., F.G.S., Brush House, Sheffield.
Booth, Henry, Abercromby Square, Liverpool.
Boothby, J. B., Everton, Liverpool.
Boswall, Capt., R.N., Edinburgh.
Boswell, William, 115, Stephen's Green, Dublin.
Bouch, Thomas, Everton, Liverpool.
Bovill, William, London.
Bourne, Rt. Hon. William Sturges, Brook Street.
Bourne, Timothy, Liverpool.
Bower, Anthony, 85, Islington, Liverpool.
Bowes, John, M.P., Streatham Castle, Durham.
Bowler, Capt., Liverpool.
Bowman, J. E., F.L.S., Gresham, near Wrexham.
Bowman, Thos., Berkeley Square, Bristol.
Bowring, John, LL.D., 1, Queen Square, Westminster.
Bowstead, Rev. T. S., Maryland Street, Liverpool.
Boyd, G. W., Winson, near Liverpool.
Bradshaw, R. S., Belfast.
Bragg, J. K., Clifton.
Brandling, John, Newcastle.
Brandling, R. W., Low Gosforth, Newcastle.
Brandon, J. J., Clifton.
Brandreth, J., M.D., Rodney Street, Liverpool.
Brandreth, James, Tavistock Place.
Branker, Henry, Wadham Coll., Oxford.
Branker, W. H., Rodney St., Liverpool.
Branson, Thomas, Sheffield.
Branwhite, Nathaniel, Bristol.
Branwhite, Nathaniel, Jun., Bristol.
Bray, Charles, Coventry.
Brentano, L. La Roche, 5, Bedford Street, Liverpool.
Brereton, Joseph, Liverpool.
Bretherton, Edward, South Hunter St., Liverpool.
Brett, R. H., F.L.S., London.
Brewster, Sir David, M.A. Cambridge, D.C.L. Oxon., LL.D., K.H., F.R.S., L. and E., St. Andrews.
Brice, Rev. H. C., Bristol.
Bridges, H. L., Clifton Hill.
Bright, Robert, Abbott's Leigh, Bristol.
Bright, Richard, Jun., M.D., Abbott's Leigh, Bristol.
Bright, Richard, M.D., F.R.S., F.G.S., 11, Saville Row.
Bright, Samuel, Liverpool.
Broadbent, William, Latchford, near Warrington.
Brockett, John Trotter, Newcastle.
Brodie, Robert, Clifton.
Brodigan, Thomas, Drogheda.
Bromby, Rev. J. E., Bristol.
Bromby, C. H., St. John's Coll., Cambridge.
Brookes, Rev. Jonathan, M.A., Everton, Liverpool.
Brooks, John, 28, Great George Street, Liverpool.
Brooks, J. H., Brazennose Coll., Oxford.
Brougham, Lord, Brougham Hall.
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Brown, George, Clifton.
Brown, George, Liverpool.
Brown, Samuel, Bristol.
Brown, Rev. Geo., M.A., Edge Hill, Liverpool.
Brown, W. A., North John Street, Liverpool.
Brown, James, Douglas, Isle of Man.
Brown, James, India Buildings, Liverpool.
Brown, Thomas, Barbadoes.
Brown, Dr., Sunderland.
Brown, J. B., Bedford Place, London.
Brown, Rev. Thos., Inneskip.
Brown, G. A., Manchester.
Browne, William, Richmond Hill, Clifton.
Browne, Robert, Liverpool.
Browne, James, Bristol.
Browne, John, Bridgewater.
Bruce, O. Tyndall, Falkland, Fifeshire.
Bruce, Rev. J. C., Newcastle.
Bruce, Robert, Frenchay, near Bristol.
Bruce, Robert, Jun., Frenchay.
Bruce, William, Middle Temple.
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Bryce, Charles, M.D., Mount Pleasant, Liverpool.
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Buchanan, Daniel, Everton, Liverpool.
Buckingham, C. J., New York.
Budd, J. P., South Hill Road, Liverpool.
Budd, John, Liverpool.
Buddicombe, Rev. R. P., M.A., F.A.S., Everton, Liverpool.
Buddicombe, W. B., Liverpool.
Buddle, John, Newcastle.

Bull, H. W., London.
Bulley, Thomas, 17, Falkner St., Liverpool.
Bunbury, Richardson, 19, Mountjoy Sq., Dublin.
Bunt, T. G., Bristol.
Bunting, Jabez, D.D., London.
Burgess, Alfred, Leicester.
Burgess, Daniel, Clifton.
Burgess, Daniel, Jun., Clifton Vale.
Burnett, George, Jun., Newcastle.
Burrell, William, Newcastle.
Burroughs, J. A., Bristol.
Burroughs, W. G., Clifton.
Burton, H. S., Carrigaholt, County Clare.
Busby, John, Monkstown Avenue, Dublin.
Bush, James, Beach Bitton, near Bristol.
Bush, Thomas, Beach Bitton.
Bush, James, Baldwin Street, Bristol.
Bush, Henry, Clifton.
Bush, George, Durdham Down, Bristol.
Bush, William, Bristol.
Bushby, W. P., Exchange Alley, Liverpool.
Bushby, F. A., Exchange Alley, Liverpool.
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Butterworth, J. H., Henbury Court, Bristol.
Byles, J. B., London.
Byng, Rev. John, Merton Coll., Oxford.

C.

Cales, Henry, Cheltenham.
Callcott, Captain G.B., Lower Crescent, Clifton.
Caly, Edward, Isle of Man.
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Campbell, Rev. Jas., D.D., Dublin.
Campbell, John, India Buildings, Liverpool.
Campbell, Colin, Toxteth Park, Liverpool.
Campbell, Rev. Colin, M.A., Newport, Salop.
Campbell, R. C., Glasgow.
Campbell, John, LL.D., Fishill, Ireland.
Capron, A., Park Row, Bristol.
Carey, Rev. Robert, Clonmel.
Cargill, William, Newcastle.
Carlisle, H. H., Bushfield Avenue, Dublin.
Carlisle, Richard, Enfield.
Carmichael, Thomas, 10, Upper Temple Street, Dublin.
Carne, C. F., 9, Bold Street, Liverpool.
Carpenter, R. L., College, York.
Carpenter, Rev. Benjamin, Nottingham.
Carpenter, W. B., Edinburgh.
Carpenter, Ph. P., Jun., Bristol.
Carr, R. L., St. Anne St., Liverpool.
Carr, I. T. J., 10, Old Church Yard, Liverpool.
Carr, Rev. William, B.D., Gomersal, near Leeds.
Carr, William, Gomersal.
Carrick, A., M.D.
Carrow, I. M., Temple, London.
Carson, J. W., M.D., F.R.S., Mount Pleasant, Liverpool.
Carson, James, Jun., M.D., Liverpool.
Carson, P. M., Mount Pleasant, Liverpool.
Carson, Joseph, Trinity College, Dublin.
Carter, Rev. Augustus, Theakstone, Yorkshire.
Case, B. C. T., Malmesbury.
Case, W. A., Garston, Liverpool.
Case, R. E., Clifton.
Case, J. Ashton, Aigburth, Liverpool.
Casin, Henry, Bristol.
Casson, Wm., Greenland St., Liverpool.
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Castle, Michael, Grove House, Clifton.
Castle, W. H., Stoke's Croft, Bristol.
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Catto, Robert, Aberdeen.
Cay, R. B., Sunderland.
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Chambers, James, Dublin.
Champion, Guy, Dublin.
Chancellor, George, Dublin.
Chanter, John, Earl Street.
Chapman, Capt. J. G., R.A., Clifton.
Chappell, Commander, R.N., Dublin Steam Packet Office, Liverpool.
Charles, S., Bristol College.
Charlesworth, Edward, British Museum.
Charters, Capt. Samuel, R.N., Bath.
Chawner, Dr. Darwin, Newark.
Chatfield, Henry, Devonport.
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Cheetham, David, Preston.
Chibborn, Edward, Cullenswood, Dublin.
Chilcott, John, Bristol.
Chilcott, Thomas, Clifton.
Cholmeley, M., Oxford.
Clanny, Rev. R., F.R.S.E., Sunderland.
Clanny, Dr., Sunderland.
Clapham, Col., Over Court.

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Clarke, W. H., London.
Clarke, James, Q. C., Recorder of Liverpool.
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Clarke, J. L., Woolton, Liverpool.
Clarke, Joshua, Bristol.
Clarke, Rev. W. B., Stanley Green, near Poole.
Clarke, Rev. Edward, M.A., Essex.
Clarke, N. D., Manchester.
Clarke, E. S., Palmerston.
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Clay, Rev. John, B.D., Adlington Hall, Cheshire.
Clayton, John, Newcastle.
Cleave, W. O., Clifton.
Clegram, W. B., Gloucester.
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Clerk, Henry, Bristol.
Clerk, Thomas, M.D., Aberdeen.
Clerk, Rev. D. M., Yatton, near Bristol.
Clerke, Major Shadwell, K.H., F.R.S., Athenæum.
Clive, Rev. William, Welsh Pool
Clutterbuck, James, Cheltenham.
Coates, William, Clifton.
Coates, William, Jun., 5, Richmond Terrace, Clifton.
Coathupe, Oliver, Redland, near Bristol.
Cobden, Richard, Manchester.
Cock, Edward, Guy's Hospital.
Cock, James, Liverpool.
Cocker, John, Salford.
Cocks, W. S., Upper Newington, Liverpool.
Cocks, J. Somers, Legh, Worcester.
Cocks, Rev. H. Somers, Legh.
Coffin, William, Llandaff.
Coglan, Thomas, Exchange Street East, Liverpool.
Colbeck, Thomas, Southampton Row.
Cole, Lord Viscount, M.P., Florence Court.
Cole, Walter K., Bristol College.
Coles, Rev. Thos., Bourton on the Water.
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Collings, D. H., Queen's Coll., Oxford.
Collins, James, M.D., 11, Norton Street, Liverpool.
Collinson, Rev. John, A.M., Gateshead.
Colville, Lieut. R., 97th. Regt., Stockport.
Comer, George, Exchange Buildings, Liverpool.
Comrie, A., London.
Condie, John, Willsonton Iron Works, North Britain.
Condie, A., North Britain.
Congreave, C., Sheffield.
Connebee, Richard, Dorking.
Conolly, John, M.D., Warwick.
Conolly, William, M.D., Castleton House, near Cheltenham.
Conybeare, John, Sully Rectory.
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Cooke, J. A., Clifton.
Cooke, George, West Derby, Liverpool.
Cooke, Isaac, Clifton.
Cooke, Samuel, Christ Church, Oxford.
Cookson, Joseph, Clifton.
Cookson, Isaac, Meldon, Newcastle.
Cooper, John, Bristol.
Cooper, J. S., M.R.I.A., Upper Merrion Street, Dublin.
Cooper, James, St. Anne Street, Liverpool.
Cooper, Paul, Isle of Man.
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Copeland, G. F., Cheltenham.
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Corrie, J. R., M.D., Birmingham.
Corrie, Thomas, Bedford St., Liverpool.
Corrie, V. B., London.
Corser, Rev. Wm., Stand, near Bury.
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Costello, Marcus, Dublin.
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Cottam, S. E., Manchester.
Coulston, T. L., Clifton Wood.
Coultherd, Wm., Newcastle-upon-Tyne.
Cowall, J. W., Gloucester.
Cowan, Charles, M.D., Bath.
Cowan, William, LL.D., Lodge Lane, Liverpool.
Cowan, Capt. T., R.N., Edinburgh.
Cowie, C. G., Liverpool.
Cowling, John, Temple.
Cowling, John, Maryland St., Liverpool.
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Cox, James, 10, Oxford St., Liverpool.

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Craigh, Hugh, Percy Street, Liverpool.
Crane, George, Swansea.
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Crawley, Rev. Wm., Brynywyn Rectory, Monmouth.
Creig, W. L., Red Castle, Castle Douglas.
Creighton, Captain, London.
Crewdson, Wilson, Manchester.
Crichton, Sir Alexander, Kent.
Cripps, Frederick, 39, Mount Pleasant, Liverpool.
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Croft, J. R., Straw Street, Liverpool.
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Crompton, Henry, Eton House, Liverpool.
Crompton, Albert, Eton House, Liverpool.
Crompton, Woodhouse, Liverpool.
Crooke, Nicholas, Christ Church, Oxford.
Croome, William, Cirencester.
Cropper, John, Everton, Liverpool.
Cropper, John, Jun., Dingle, Liverpool.
Cropper, Edward, Dingle, Liverpool.
Crosfield, Wm., Mason Street, Liverpool.
Crosfield, John, Temple Court, Liverpool.
Crosfield, Simon, Bedford St., Liverpool.
Cross, B. J., Kingsdown, Bristol.
Cross, William, Clifton.
Cross, Thomas, Bristol.
Cross, T. B., Chorley, Lancashire.
Crosse, J. A., Broomfield, near Taunton.
Crossfield, Joseph, Warrington.
Crouch, E. A., Penzance.
Cruickshanks, Alexander, Boulogne.
Crum, Walter, Glasgow.
Crump, John, Woodside, Cheshire.
Culdwell, J.S., Linley Wood, Staffordshire.
Cull, Richard, London.
Cumberland, G., Bristol.
Cumming, Rev. Professor, F.R.S., F.G.S., Cambridge.
Cumming, George, M.D., Denbigh.
Cunningham, James, Clifton.
Cunningham, James, Jun., Clifton.
Cunningham, John, Wood St., Liverpool.
Cunningham, George, Oak Vale, near Liverpool.
Cunningham, William, Castle Pollard.
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Currie, William, Q.C., 37, Summer Hill, Dublin.
Currie, W. W., Ellerslie, Liverpool.
Curry, P. F., Knotty Ash, near Liverpool.
Curtis, B. W., Bristol.
Curtis, W., Alton, Hants.
Curtis, John, F.L.S., 11, Robert Street, Hampstead Road.
Cuthbert, S. T., Clifton.

D.

Dakin, Thomas, London.
Dale, J. C., Granville's Wootten, Dorset.
Dale, T. A., Hanover Street, Liverpool.
Dale, E. H., Bristol.
Dale, Henry, North Shields.
Dale, Rev. P. S., Holland's Green, Warrington.
Dalgleish, Robert, Wigan.
Dalton, John, D.C.L. Oxon., F.R.S., &c., Manchester.
Dalton, J. S., Mount Vernon, Liverpool.
Danger, William, Durdham Down Lodge, Bristol.
Daniel, Edward, Jun., St. George's, Somerset.
Daniel, Thomas, Henbury, near Bristol.
Daniel, Thomas, Jun., Sneed Park, near Bristol.
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Darthez, S. T., Clapham Park.
Daubeny, J. W., Cote, near Bristol.
Davey, Gen. W., Tracey Park, near Bath.
Davey, Richard, Redruth, Cornwall.
Davies, Thomas, Montpelier, Bristol.
Davies, Theodore, Nailsea, near Bristol.
Davies, David, M.D., Bristol.
Davies, W. W., Coate Bank, Westbury.
Davies, John, M.D., 31, Lennox Street, Dublin.
Davies, Rev. Robert, M.A., Brownlow Street, Liverpool.
Davies, Rev. Richard, B.A., Brownlow Street, Liverpool.
Davies, Walter, Liscard, Cheshire.
Davies, Edward, Wrexham.
Davies, John, Abergeley, Denbigh.
Davies, James, Lyceum Place, Liverpool.
Davis, Francis, Waterford.
Davis, Joseph, Westbury-upon-Tyne.
Davy, Rev. Dr., Master of Caius College, Cambridge.
Dawell, John, Bristol.
Dawell, Stephen, Abbott's Leigh, Hunts.
Dawson, Charles, Llangollen.
Dawson, John, Rodney Street, Liverpool.
Dawson, Robert, Sandwell Cottage, Birmingham.
Dawson, Joseph, 20, Stafford Street, Liverpool.
Dawson, Edw., Aldcliffe Hall, Liverpool.
Day, Alfred, Bristol.

Day, Joseph H., Bristol.
Day, John, Peckham.
Day, J. D., Brazennose College, Oxford.
Day, J., Llangollen.
Deane, Sir Thomas, Cork.
Deane, Alexander, Cork.
De Beauvoir, Sir John E., Bart., Albemarle Street.
De Butts, Rev. G., A.M., Crickhowel, Glamorganshire.
Denham, Capt. H. M., R.N., Toxteth Park, Liverpool.
Denny, Henry, Leeds.
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De Soyres, Rev. F., Siddlesham, Sussex.
Dick, Dr. Paris, Bristol.
Dicker, J. R., Woodside, Cheshire.
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Dickson, Rev. T. B., Whittle, near Preston.
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Dillwin, L. W., Spelty Hall, Swansea.
Dix, John, Jun., Somerset Terrace, Bristol.
Dixon, James, Birkenhead, Cheshire.
Dixon, James, Oxford.
Dixon, William, Parish Office, Liverpool.
Dixon, William, Jun., Abercromby Square, Liverpool.
Dixon, J. D., Everton, Liverpool.
Dobbs, A. A., Birkenhead, Cheshire.
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Douglass, Rev. William, Prebendary of Durham.
Dow, Robert, M.D., Waterford.
Dowell, Rev. Henry, M.A., Axminster.
Drake, John, Bedminster.
Dublin, His Grace the Archbishop of.
Du Buisson, Thomas, Wandsworth.
Duckworth, Robinson, 2, Canning Street, Liverpool.
Dudgeon, Robert, Mount Pleasant, Liverpool.
Dudgeon, John, Edinburgh.
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Duke, Valentine, M.D., Dublin.
Dumbell, G. W., Isle of Man.
Dunalley, Lord, Kilbay, Nenagh.
Dunbar, David, Newcastle-upon-Tyne.
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Duncan, J. R., Dumfries.
Duncan, Robert, Dumfries.
Dungannon, Lord, M.P., Wickham Park, Northampton.
Dunlevie, C. T., Brunswick St., Liverpool.
Dunn, William, Hedgfield.
Dunsford, William, Park Place, Clifton.
Duppa, T. D., Salop.
Durbin, F. J., Trinity Coll., Cambridge.
Durby, Abraham, Colebrook Dale.

E.

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Earle, Hardman, Exchange Buildings, Liverpool.
Eaton, Rev. George, Norwich.
Eaton, Rev. George, The Pole, near Warrington.
Eaton, Joseph, Bristol.
Eastwicke, W. H., Heynsham.
Eckersall, John, Bath.
Edgar, John Foy, Bristol.
Edgworth, Francis, Bristol.
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Edwards, Thomas, Bristol.
Edwards, G. O., Redland, near Bristol.
Edwards, S. C., Long Ashton, Somerset.
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Egerton, W. G., Oulton Park, Cheshire.
Egerton, Rev. William, Hodnet, Salop.
Eginton, Harvey, Worcester.
Eglington, Sam., 88, Islington, Liverpool.
Eglington, J. T., 88, Islington, Liverpool.
Elgin, Edward, York.
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Ellis, Francis, Bristol.
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Elton, Ar. H., Bristol.
Elton, C. A., Bristol.
Elverson, James, Bushby, Leicestershire.

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Elwin, F. H., London.
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Errington, William, Hartford.
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Exall, William, Reading.
Exley, Thomas, M.A., Bristol.
Eyes, Edward, Everton, Liverpool.
Eyes, Edward, Jun., Liverpool.
Eyton, T. C. Eyton, Wellington, Salop.
Eyton, John, Holywell.
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Fielden, John, M.P., Todmorden, Lancas.
Fielden, Joshua, Todmorden, Lancashire.
Fielden, Rev. Robt., Bebbington, Cheshire.
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Fletcher, Robert, Exchange, Bristol.
Fletcher, Angus, Athenæum.
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Fox, G. C., Grove Hill, Falmouth.
Fox, Edwin, Brislington.
Fox, F. K., Brislington.
Fox, C. P. Brislington.
Fox, Robert Were, Falmouth.
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Greenwell, William, North Shields.
Greeves, Augustus F. A., Nottingham.
Greg, R. H., Manchester.
Greg, W. R., Manchester.
Greg, Samuel, Manchester.
Gregg, R. H., Norcliffe, Cheshire.
Greig, Charles, Bristol.
Gretton, Rev. R. H., Rector of Nantwich.
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Guppy, Samuel, London.
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Hardwicke, William, Surgeon, London.
Hare, John, Springfield.
Hare, C. B., Bristol.
Hare, Charles, Bristol.
Hare, W. C., Bristol.
Harford, J. S., Bristol.
Harford, Somers, Tirhowy, Abergavenny.
Harford, W. H., Bailey Wood, Somerset.
Hargreave, James, Leeds.
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Harris, William, Bristol.
Harris, Edward, Meath.
Harris, Joseph, Chapel Villa, Liverpool.
Harris, G. F., Harrow on the Hill.
Harris, Wm. Snow, F.R.S., Plymouth.
Harrison, John, Bristol.
Harrison, John, Nottingham.
Harrison, T. E., Whitburn.
Harrison, Wm., Fulwell Grange, Durham.
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Harvey, R. E., Islington, Liverpool.
Harvey, Alexander, Glasgow.
Harvey, John, Ripon.
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Harwood, Reynold, Edinburgh.
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Hasseli, Charles, Bristol.
Hassell, William, Bristol.
Hastings, William, Huddersfield.
Hawkes, William, Birmingham.
Hawkshaw, John, Manchester.
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Hayes, Rev. H., Bath.
Hayes, John, Edinburgh.
Haynes, Rev. Thomas, Bristol.
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Healey, Elkanah, Liverpool.
Healey, S. R., Edge Hill, Liverpool.
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Heath, Rev. Thomas, Chester.
Heaton, Charles, Endon, Staffordshire.
Heaven, C. G., Bristol.
Hebson, Douglas, Liverpool.
Hedley, Dr., Mayor of Morpeth.
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Heigham, Capt., 4th Dragoon Guards.
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Hellicar, Joseph, Hotwells, Bristol.
Hellicar, Valentine, Bristol.
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Hill, Charles, Distillery, Bristol.
Hill, Jeremiah, Bristol.
Hillhouse, Martin, Clifton.
Hillhouse, George, Combe, Gloucestersh.
Hilton, Major, Allerton Hall.
Hilton, James, Edge Hill, Liverpool.
Hilton, Sir John, Conway.
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Hodgson, Richard, M.P.
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Hutching, Rev. A., London.
Hutchings, E., Keynsham, near Bristol.
Hutchinson, Frederick, 7th Regiment Fusileers.
Hutchinson, James, Paris.
Hutchinson, Captain C., North Hall, Wigan.
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Huxtable, Edgar, Bristol.
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Jones, R. P., Charfield, Glostershire.
Jones, George, Bristol.
Jones, W. C. Bristol.
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Jones, E., Brecon.
Jones, R. Wynne, Beaumaris.
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Price, H. C., Westbury.
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Prichard, Edward, Ross.
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Prittie, Henry, Corville, Co. Tipperary.
Proctor, Thomas, Birmingham.
Prosser, Samuel, Blackheath.
Protheroe, M. D., Clifton.
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Purdon, Simon, Devonport.
Purdon, Rev. W. J., M.A., Aigburth, Liverpool.
Purdy, Richard, Lower Ormond Quay, Dublin.

Q.

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Queckett, J. T., Langport, Somerset.
Quinn, Richard, Liverpool.
Quirk, George, Isle of Man.
Quirk, J. R., Isle of Man.
Quirk, R., Isle of Man.

R.

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Radcliffe, Richard, Town Hall, Liverpool.
Radcliffe, Richard, Jun., West Derby, Liverpool.
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Rae, Ebenezer, Liverpool.
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Raikes, Rev. Chancellor, Chester.
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Randolph, Rev. J. H., Bildeston, Suffolk.
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Rankin, Robert, Clifton.
Rankin, Robert, Jun., Chief Justice of Sierra Leone.
Rankin, Rev. Charles, Brislington, near Bristol.
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Rathbone, William, Jun., Liverpool.
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Rawson, John, Halifax.
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Ricardo, M., Brighton.
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Rickards, Richard, Clifton.
Rickett, Richard, Bristol.
Rickett, Henry, Brislington, Bristol.
Riddell, Sir J. M., Bart., Strontian, Scotland.
Riddell, Thomas, Strontian.
Riddle, Isaac, Bristol.
Riddle, T. H., Bristol.
Riddle, W. L. Bristol.
Ridgway, John, Staffordshire Potteries.
Ridgway, Joseph, 8, India Buildings, Liverpool.
Ridgway, J., India Buildings, Liverpool.
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Ridout, Geo., Newland, Gloucestershire.
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Robinson, Rev. Wm., Dinham Rectory.
Robley, Henry, Clifton.
Rodick, Thomas, Gateacre, Liverpool.
Rodman, S. W., New Bedford.
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Sealey, H. N., Clifton.
Sealey, George, Clifton.
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Shaw, R.N., Springfield, Liverpool.
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Sinclair, Archibald, Edinburgh.
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Smith, H. L. Southam, Warwicks.
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Smith, Captain George, R.N., London.
Smith, W. H., Birmingham.
Smith, Joseph, Manchester.
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Spence, John, Q.C., London.
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Stephens, Henry, Bristol.
Stephens, John, Bristol.
Stephens, Thomas, Tynemouth.
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Stiff, William, Bristol.
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Stock, Thomas, Bristol.
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Thorpe, Rev. Charles, Warden of University, Durham.
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Tuckett, P. D., Frenchay, Bristol.
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Tudor, Richard, Bushfield, Clontarf, Co. Dublin.
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West, William, Observatory, Clifton.
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RELATING TO THE

ADMISSION OF MEMBERS,

AND

PAYMENT OF SUBSCRIPTIONS AND ACCOUNTS.

Members.

All persons who have attended the First Meeting (at York in 1831) shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies, publishing Transactions, in the British Empire, shall be entitled in like manner to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions shall be entitled in like manner to become Members of the Association.

All Members of a Philosophical Institution, recommended by its Council or Managing Committee, shall be entitled in like manner to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Members of the Association, subject to the approval of a General Meeting.

Subscriptions.

The amount of the *Annual Subscription* shall be One Pound, to be paid in advance upon admission; and the amount of the *Composition in lieu thereof* Five Pounds.

Subscriptions shall be received by the Treasurer or Secretaries.

Arrears.

If the Annual Subscriptions of any Member shall have been in arrear for Two Years, and shall not be paid on proper notice, he shall cease to be a Member; but it shall be in the power of the Committee or Council to reinstate him on payment of arrears.

Accounts.

The Accounts of the Association shall be audited Annually, by Auditors appointed by the Meeting.

I. Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

Presidents.	Vice-Presidents.	Local Secretaries.
The EARL FITZWILLIAM, D.C.L. F.R.S. F.G.S. &c. York, September 27, 1831.	Rev. W. Vernon Harcourt, M.A. F.R.S. F.G.S.	William Gray, Jun. F.G.S. Professor Phillips, F.R.S. F.G.S.
The REV. W. BUCKLAND, D.D. F.R.S. F.G.S. &c. Oxford, June 19, 1832.	Sir David Brewster, F.R.S.L. & E. &c. Rev. W. Whewell, F.R.S. Pres. Geol. Soc.	Professor Daubeny, M.D. F.R.S. &c. Rev. Professor Powell, M.A. F.R.S. &c.
The REV. ADAM SEDGWICK, M.A. V.P.R.S. V.P.G.S. Cambridge, June 25, 1833.	G. B. Airy, F.R.S. Astronomer Royal, &c. John Dalton, D.C.L. F.R.S.	Rev. Professor Henslow, M.A. F.L.S. F.G.S. Rev. Wm. Whewell.
Sir T. MACDOUGAL BRISBANE, K.C.B. D.C.L. F.R.S.L. &E. Edinburgh, September 8, 1834.	Sir David Brewster, F.R.S. &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S.L. & E. &c. Sir John Robison, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. Dublin, August 10, 1835.	Viscount Oxmantown, F.R.S. F.R.A.S. Rev. W. Whewell, F.R.S. &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd.
The MARQUIS OF LANSDOWNE, D.C.L. F.R.S. &c. Bristol, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S. F.G.S. J. C. Prichard, M.D. F.R.S.	Professor Daubeny, M.D. F.R.S. &c. V. F. Hovenden.
The EARL OF BURLINGTON, F.R.S. F.G.S. Chan. Univ. Lond. Liverpool, September 11, 1837.	The Bishop of Norwich, P.L.S. F.G.S. John Dalton, D.C.L. F.R.S. Sir Philip Grey Egerton, Bart. F.R.S. F.G.S. Rev. W. Whewell	Professor Traill, M.D. Wm. Wallace Currie. Joseph N. Walker, Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S. F.G.S. &c. Newcastle-on-Tyne, August 20, 1838.	The Bishop of Durham, F.R.S. F.S.A. The Rev. W. Vernon Harcourt, F.R.S. &c. Prideaux John Selby, Esq. F.R.S.E.	John Adamson, F.L.S. &c. Wm. Hutton, F.G.S. Professor Johnstone, M.A., F.R.S.

II. Table showing the Members of Council of the British Association from its Commencement, in addition to Presidents, Vice-Presidents, and Local Secretaries.

General Secretaries.	Rev. Wm. Vernon Harcourt, F.R.S., &c.	1832—1836.
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	R. I. Murchison, F.R.S. F.G.S.	1836, 1837.
	Rev. G. Peacock, F.R.S. F.G.S., &c.	1837.
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Francis Baily, V.P. and Treas. R.S.	1837.
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Rev. Professor Buckland, D.D. F.R.S., &c.	1833, 1835.
Robert Brown, D.C.L. F.R.S.	1832, 1834, 1835.
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M. I. Brunel, F.R.S., &c.	1832.
Rev. T. Chalmers, D.D. Prof. of Divinity, Edinburgh	1833.
Professor Christie, F.R.S., &c.	1833—1837.
William Clift, F.R.S. F.G.S.	1832—1835.
John Corrie, F.R.S., &c.	1832.
Professor Daniell, F.R.S.	1836.
J. E. Drinkwater	1834, 1835.
The Earl Fitzwilliam, D.C.L. F.R.S., &c.	1833.
Professor Forbes, F.R.S.L. & E., &c.	1832.
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